

# Grown in Gravel

The Study of Geological Agriculture



## 2014 Edition

RICHARD C. CAMPBELL



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## **2014 EDITION**

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BY

RICHARD C. CAMPBELL

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**I.**

**Forward by Author- 5 Contents**

**II.**

**Welcome – 6**

**III.**

**Gravel Gardening Benefits – 7**

**IV.**

**The Issues with Soil – 8**

**V.**

**Current Gravel Methods - 9**

**VI.**

**Geological Agriculture Definitions – 12**

**VII.**

**Gravel Gardening Basics – 15**

**VIII.**

**Materials – 16**

**IX.**

Gravel Gardening Seed Testing – **17**

I.

Tennessee State University – Germination Study – **20**

II.

Transplanting From Gravel to Soil – **25**

III.

Water Testing - **26**

X.

Building Your Gravel Garden – **27**

XI.

Gravel Gardens In Action **33**

I.

Cucumbers, Lettuce, Marigolds, Gardens, Tulips and more – **34** XII.

Nutrition Testing : Cucumbers – **49**

XIII.

Nuances of Gravel Gardening - **50**

I.

Water Behavior – **51**

II.

Root Behavior – **53**

III.

Gravel Garden Eco System– **59**

IV.

George Washington University - Gravel Composting Study - **60**

V.



Living with Your Gravel Garden **64**

XIV.

Alternative Applications **68**

I.

Greenhouse – **71**

II.

Sample Configurations – **72**

III.

Gravel Gardening on Cement **76**

IV.

Hay gravel gardens- **79**

V.

Rooftop Gardens – **80**

VI.

Small Farms – **83**

VII.

Survival gravel gardens **88**

XV.

Tools of Gravel Gardening – **89**

XVI.

Gravel Gardening Costs – **90**

XVII. Things to Remember – **91**

XVIII. Education Activity – **92**

XIX.

Gravel Gardening Gallery 2014 – **99**

XX.

Glossary of Terms - 115<sub>XXI</sub>.

To Soil Less – 116

## **Forward by Author**

Each year we issue a new edition in the study of geological agriculture or gravel gardening.

This years' 4<sup>th</sup> edition includes academic contributions from George Washington University (GWU) and Tennessee State University (TSU).

Professors at GWU examined geological

characteristics, while professors and students at TSU assessed baseline agriculture aspects of geological agriculture.

Combined, these studies begin to shape the academic building

blocks of this new science.

This edition includes a 16-page gravel gardening gallery of the

past year along with the first geological agriculture glossary of terms, which introduces a variety of new terms to describe the process of the rock based crop sustainment.

It has been a fulfilling yet challenging journey seeking to bring to reality the notion that rocks can produce crops; getting life out of something thought dead.

For now, I refer to

myself as Pheidippides of ancient Greece who is the central figure in the story of the marathon. He is said to have run the 26 miles from Marathon to Athens to deliver news of a military victory against the Persians. Like Pheidippides, I find myself running to tell the news that rocks can grow crops.

Since this is still a relative secret in society of news untold, my

journey is not over.

Soon however, my run should become easier as society begins to embrace the notion of geological agriculture.

On the back cover in fine print, you may notice the phrase “Make the workmanship surpass the materials” by Ovid, a Roman poet. My mentor and uncle, Dr. Thomas Logan said this to me at the completion of this book.

But his statement is meant more for you than me.

To

rephrase, the material is gravel or simple rocks; what you do with them is what matters.

The workmanship with gravel to produce food surpasses the gravel itself. Simply put, make gravel gardening surpass the gravel.

As a young science, much is to be discovered, revealed and fine tuned with geological agriculture. As an individual, I can only take this new science and all it has to offer so far.

At

some point, geoag should take on a life of its own and society can take a step closer towards food security.

We applaud all those who have been courageous enough to take a second look at rocks. If rocks + seeds + water = food, what does this mean for world hunger?

Everything we know so far about geological agriculture is included in this 4<sup>th</sup> edition.

We

hope you find it useful.

Good luck and enjoy.

**Welcome**

Welcome to the world of geological agriculture. Your first step in alternative gardening 2.0; gravel gardening.

This guide will outline the steps necessary to incorporate gravel gardening techniques and practices into your home and growing environments.

You will learn 1) the basics and the

science behind gravel based agriculture, 2) materials required, and 3) Various applications and management techniques. Once you lay your gravel garden correctly, you should not have to change nor replace your gravel for many years, while producing crops each year.

Geological Agriculture is the process of growing vegetables and flowers in an all rock or gravel environment. Also known as geoagriculture or gravel gardening, this method of cultivating crops enables vegetation to occur and sustain itself with limited to no use of soil and fertilizers..

The study of geological agriculture is in its infancy as it was discovered by accident in 1994 by Dr.

Thomas Logan and Richard Campbell.

To Soil Less<sup>TM</sup> was founded by Richard Campbell in 2009 to

research the attributes of geological agriculture and share this approach to crop cultivation with the greater society.

Each year To Soil Less

<sup>TM</sup> produces a new manual on geological agriculture called Grown in Gravel, which includes the body of research accumulated since the prior year.

In this 2014 version of

Grown in Gravel, contributions from the Tennessee State University School of Agriculture and the George Washington University School of Applied Sciences are included along with observations conducted

at



Lowell

School

K

-8

in

Washington, DC

and

at

Yu

Ying

Elementary

School

in

Washington, DC.

Review the entire manual prior to starting the construction of your gravel garden. You can misstep and have no growth if certain procedures are not followed. All images taken are of crops grown in gravel except where noted.

## Gravel Benefits

There are several key benefits to adopting gravel gardening techniques to the gardening, agriculture or crop cultivation process as follows:

**1.**

**Reduced Soil Use** – When you go gravel, you no longer need to use soil to grow your vegetables, flowers, and most fruits. You can mix soil with gravel if you

choose, but gravel by itself can cultivate crops. This point has been fully substantiated by the Tennessee State University “Germination Study”.

2.

**Less Watering** – Proper construction requires a semi-enclosed environment where water is held in the gravel gardening system longer. Consequently, outdoor gravel gardens use over 50% less water.

3.

**Reduced reliance on Fertilizers** –The gravel itself provides the basic nutrient materials to sustain plant growth. Fertilizers are not necessarily needed in the cultivation process with gravel.

4.

**Less Weeding** – Proper construction requires several layers of plastic and lawn fabric underneath the gravel. The barrier of lawn fabric and plastic prevents soil based weeds from growing in the gravel garden. Consequently, gravel gardens reduce the need for weeding and nearly eliminates the need for weeding products.

Airborne weeds will still

land on the gravel and can grow.

5.

**Cultivation Degradation** – Is soil, crop production degrades the nutrient value of the soil causing the need for fertilizers and crop rotation. With gravel, after each harvest, the remaining leaves and vines decompose and decay back into the gravel bed, enhancing the growing environment each year instead of degrading it.

6.

**All Natural** – The primary ingredients of gravel gardens are river pea gravel, sand, and cotton, which are all natural materials.

7.

**Less Cost** – Once you set up your gravel garden, it can last 20+ years without the need to more gravel and sand, while producing crops each year. A bag of gravel costs the same as a bag of soil.

By reducing the need to buy fertilizers, weed and feed chemicals, you spend less.

8.

**Drought Resistant** – With proper construction, a gravel garden may be 100+ degrees on the outside, but remains a cool 75 to 80 degrees on the inside. The temperature contrast provides a moist growing environment during in drought like conditions.

9.

**Organic** – Farmers and commercial growers can adopt principals of gravel gardening to better the chances of attaining the certified organic status.

10.

**Nutrient Value** When testing the nutrient value of crops grown in gravel, the results have shown that gravel grown crops have the same if not better nutritional value as soil grown crops.

The 10 benefits of gravel gardening provides practitioners an array of opportunities to make their gardening process more efficient. The next few slides provide an overview of the gravel gardening techniques needed for a successful gravel garden growing environment.

## The Issues with Soil

Soil is the cornerstone of gardening and agriculture but it comes with several key challenges, including but not limited to:

1.

**Soil Degradation** – Every year, soil that has produced crops lose nutrient value.

Continuous cultivation can reduce soil productivity, requiring fallow seasons, crop rotation, cover cropping, and other supplements to add nutrients back to the

crop rotation, cover cropping, and other supplements to add nutrients back to the soil.

2.

**Fertilizers** – Because nutrients are extracted out of the soil with each growing season, commercial producers and home gardeners supplement soil with fertilizers.

Chemical

fertilizers are added when seeding or planting, throughout the season to encourage plant growth, and at the end of the season in preparation for the following year.

Over

time, chemical fertilizer pollutes the environment.

3.

**Soil erosion** – Heavy rains can erode soil and any nutrients associated with the soil, which

can

become

run-off

into

lakes

and

rivers,

consequently

polluting

the

environment.

The estimated annual costs of public and environmental health losses related to soil erosion exceeds \$45 billion each year. *Wikipedia*.

4.

**Money** – Soil erosion and decomposition over time can cause home owners to buy new soil each year.

Commercial farmers also spend thousands in fertilizers each year, keeping costs high.

5.

**Soil Variability** – At any given time, the chemical and physical properties of soil can vary considerably from

clay

like

soil,

to

sand

to

unproductive

dirt,

which

can

reduce

reduce

vegetable production and quality.

6.

**Absorption** – Soil absorbs the water applied to plants and vegetables. When soil is dry, soil can hold onto water so tightly that it is not available for plants. Soil consumes and absorbs water where sand holds and releases water.

7.

**Critters** – Bugs, worms, insects, and spiders inhabit the soil and can either help or hinder plant growth. Underground ant hills, animals that bore holes in the ground, and random bugs crawl, creep, and interface with your vegetables. Some insects even feed on vegetable plant roots and burrow deep inside to lay eggs to complete their life cycle.

8.

**Topsoil** – The consumption of topsoil is a major environmental concern.

Without

topsoil, little plant life is possible.

Conventional agriculture encourages the depletion  
of topsoil .

Sustainable techniques attempt to slow erosion to build organic matter in the soil. The United States alone loses 2 billion tons of topsoil per year. This is of great ecological concern as one inch of topsoil can take 500 years to form naturally.

*The*

*topsoil reference provided by Wikipedia.*

Agricultural historians likely know that the agricultural community was once led and operated by geologists (Shaler, 1891). This reference to geologists as agents within the crop production community is the oldest reference found to date



within the crop production community is the oldest reference found to date.

definition

of

soil

was

developed

as “crushed

classification is still used in dictionaries today. By the 1930’s, other scientists asserted that soil was an independent layer of earth and was to be considered independent from any rock classification (Gedroiz, 1927). From this point on, the agriculture community focused its study on soil as the primary growing medium for crops and vegetation.

Attempts have been made

to grow crops with land based rocks, but were determined to be ineffective (Soil Survey Division, 1993).

During this period in the late 1800’s, the

or

disintegrated

rock

and

humus.”

This

Contemporary scientists and researchers have touched on different forms of using rocks or gravel in agricultural production or sustainment. The University of Missouri has been working on the *Missouri Gravel Bed* – This group

developed a method of using gravel to store bare root trees during the winter. During the winters, many trees are dug up and shipped and stored bare root, where the roots are exposed. These roots are semi dormant. The theory with the Missouri Gravel Bed is that the roots would be better sustained if placed in gravel instead of being wrapped and held in cold storage.

In the final report, they indicate that gravel, and the way they configure it, is not a growing method but a method to help sustain semi dormant root systems. (Starbuck, 2006)

A key text in the relevant work for geological agriculture is found in the book, *Rocks for Crops* by Dr Peter Van Straaten who outlines the principles of agrogeology.

Straaten is a noted

faculty member of the Land Resource Science Department University of Guelph in Ontario Canada.

He

asserts “Agrogeology

-

The

application

of

geology

to

agricultural

practice,

examining how soil nutrients, pH and soil structure can be improved using

naturally occurring, mineral-rich rock materials. Rocks such as potash, gypsum, limestone and dolomite are rich in nutrients and can be used as fertilizers – directly added to the soil. One of the biggest challenges is replacing and increasing phosphates in the soil. Geologists can play an important role in identifying, mapping and utilizing phosphate-rich rocks. Rocks such as scoria and pumice can be used to help retain water in the soil, and rocks such as limestone and dolomite can be used to decrease the acidity of the soil, raising the pH.” (Straaten, 2005) A group out of Massachusetts at

[www.remineralize.org](http://www.remineralize.org) is a nonprofit organization assisting the worldwide movement of remineralizing soils with finely ground rock dust, sea minerals and other natural and sustainable means to increase the growth, health, and nutrient value of all plant life. Adding minerals and trace elements is vital to the creation of fertile soils, healthy crops and forests, and is a key strategy to stabilize the climate. This group works in Costa Rica and in other places using rock dust to act as fertilizers to soil. (Campe, n.d.)

Gravel is used in the agriculture landscape in several fashions.

Unless we are missing a

specific use, we believe that they are:

- 1) Gravel is commonly used as a mulch, but the plants themselves are being grown in the soil underneath;
- 2) Bamboo plants are supported in gravel filled vases, but the bamboo was not cultivated from seed in the gravel.
- 3) The Missouri gravel bed is also a method of storing bare root trees in gravel during the winter, but the trees were grown in the ground.
- 4) Hydroponics uses gravel as a growing substrate, but hydroponics is a costly indoor system that requires constant electricity and fertilized water to provide nutrients to plants;
- 5) Agrogeology out of Canada proclaims that you can add certain rocks to soil and use rocks as a fertilizer, but here soil is still the primary growing environment;
- 6) Remineralization is where you take rocks and crush it to dust and add it as a fertilizer to soil, where again it is all about the soil.

What we believe is different is that you can cultivate crops outdoors from seed to full harvest for many years

in gravel-only environments absent of any fertilizer and soil.

The only

materials required, include

sedimentary gravel, sand, plastic, cotton fabric, limited water and seeds.

The fertilizers and nutrients for the plants come from the gravel and the sand is used to store the water.

Each of these relevant methods are similar

in concept

to geological agriculture. These

methods substantiate the foundation that rocks have nutrients suitable for plant life support to some degree. Geoagriculture takes these processes a step further by using rocks only to grow

crops.

With

previous

methods,

the

rocks

are

used

as

fertilizers

in

soil.

With

geoagriculture, the gravel is the growing medium without the use of soil.

To better understand the science behind gravel gardening, we must first explore the relevant definitions related to geology and agriculture.

The next few pages provide

definitions that begin with geological references and then move into agricultural and general sciences definitions.

**Rocks** – A relatively hard, naturally occurring mineral material. Rock can consist of a single mineral or of several minerals that are either tightly compacted or held together by a cement like mineral matrix. The three main types of rock are igneous, sedimentary, and metamorphic.

**Sedimentary rocks** A types of rock that forms by the deposition of material at the

Earth's surface and within bodies of water (rivers, lake, and oceans).

Sedimentation is the collective name for processes that cause mineral and/or organic particles (detritus) to

settle and

accumulate

into

a rock. Particles

that

form

a

sedimentary rock

by

accumulating are called sediment. Before being deposited, sediment was formed by weathering

and

erosion

in

a

source

area,

and

then

transported

to

the

place

of

deposition by water, wind, mass movement or glaciers which are called agents of denudation.

The sedimentary rock cover of the continents of the Earth's crust is extensive. Most sedimentary rocks contain either quartz (especially siliciclastic rocks) or calcite

(especially  
carbonate  
rocks).

However,

the

origin

of

the

minerals

in

a

sedimentary rock is often more complex than those in an igneous rock. Minerals in a sedimentary rock have formed by precipitation during sedimentation.

**Lithification** The process of converting soft, unconsolidated sediments into hard rock.

**Limestone -**

A

sedimentary

rock

consisting

predominantly

of

calcium

calcium

carbonate,

varieties of which are formed from the skeletons of marine microorganisms and coral.

**Calcite** - A common constituent of sedimentary rocks, limestone in particular, much of which is formed from the shells of dead marine organisms. Approximately 10% of sedimentary rock is limestone.

**Sand** - A sedimentary material consisting of small, often rounded grains or particles of disintegrated rock, smaller than granules and larger than silt. Although sand often consists of quartz, it can consist of any other mineral or rock fragment as well. Coral sand, for example, consists of limestone fragments. Used as drainage properties in construction and other industries.

**Now it is time to review key definitions of gardening and agriculture.**

**Soil** – The portion of the Earth's surface consisting of disintegrated rock and humus.

**Germination** – The beginning of growth, as of a seed, spore, or bud. The germination of most seeds and spores occurs in response to warmth and water.

Dormant seeds are

very dry and require the absorption of water to initiate the metabolic processes of respiration and begin to digest their stored food. Respiration requires the presence of oxygen, which must be sufficiently available in the soil for *germination* to proceed, so the

soil

must

be

wet

but

not



not

so

waterlogged

as

to

make

oxygen

inaccessible.

Temperatures must be above freezing (zero degrees Celsius) but not excessively hot (not

more

than

about 45

degrees

Celsius).

If

conditions

are

right,

a

radicle

(an

embryonic root) emerges from the seed coat, anchoring the seed; it then grows and puts out lateral roots.

The image shown to the left is that of a garlic root system that has formed in sedimentary gravel.

**Nitrogen fixation** – The process by which free nitrogen from the air is combined with

other elements to form inorganic compounds, such as ammonium ions, which can then be converted by nitrification into nutrients that can be readily absorbed by plants and other organisms for incorporation into more complex organic compounds. Atmospheric nitrogen is also fixed industrially under high pressure and heat to form ammonia, as in the production of fertilizers.

All living organisms are dependent on nitrogen fixation and would ultimately die without it.

**Nitrogen cycle** – The continuous sequence of events by which atmospheric nitrogen

and nitrogenous compounds in the soil are converted, as by nitrification and nitrogen fixation, into substances that can be utilized by green plants, the substances returning to the air and soil as a result of the decay of the plants and denitrification.

**Plants** Structure, growth and development - Most of the solid material in a plant is taken from the atmosphere. Through a process known as photosynthesis, most plants use the energy in sunlight to convert carbon dioxide from the atmosphere, plus water, into simple sugars. (Parasitic plants, on the other hand, use the resources of its host to grow.) These sugars are then used as building blocks and form the main structural component of the plant. Chlorophyll, a green-colored, magnesium-containing pigment is essential to this process; it is generally present in plant leaves, and often in other plant parts as well.

### **More Key Definitions from Agriculture**

**Plants** - Plants usually rely on soil primarily for support and water (in

quantitative terms), but also obtain compounds of nitrogen, phosphorus, potassium, magnesium and other elemental nutrients. Epiphytic and lithophytic plants depend on air and nearby debris for nutrients, and carnivorous plants supplement their nutrient requirements with insect prey that they capture.

For the majority of plants to grow successfully they also require oxygen in the atmosphere and around their roots (soil gas) for respiration. Plants use oxygen and glucose (which may be produced from stored starch) to provide energy.[30] Some plants grow as submerged aquatics, using oxygen dissolved in the surrounding water, and a few specialized vascular plants, such as mangroves, can grow with their roots in anoxic conditions.

**Phosphorus** The vast majority

of phosphorus compounds

are consumed as fertilizers.

Phosphate minerals are fossils. Low phosphate levels are an important limit to growth in some aquatic systems. The chief commercial use of phosphorus compounds for production of fertilizers is due to the need to replace the phosphorus that plants remove from the soil, and its annual demand is rising nearly twice as fast as the growth of the human population.

The phosphorus cycle originates in sediments, the main reservoir for phosphates, while rainwater contains a minimal amount of this nutrient, so it is classified as a sedimentary cycle.

However, substantial environmental damage is a product of mining phosphorous deposits on islands.

The major source of phosphorus in soil is apatite, a calcium-phosphate mineral, and the weathering of terrestrial deposits releases phosphorus, some of which goes into rivers, lakes, or oceans.

Plants absorb phosphorus in the form of phosphate, and

herbivores consume the plants, taking in the nutrient. Phosphate is then released back to the soil or water source by animal excretion, this recycling process is a significant source of phosphorous in freshwater ecosystems.

Also, when organisms die, the decomposers reduce the phosphorus into organic forms, therefore returning it to the soil, which aids the cycle in continuing.





<http://andersonapes.pbworks.com/w/page/12868221/1st%20Period%20Phosphorus%20Cycle><sup>14</sup>

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denitrification.

**Hydrology** – The scientific study of the properties, distribution and effects of water on the Earth's surface, in the soil and underlying rocks, and in the atmosphere.

**Water** – A clear colorless tasteless odorless liquid that is essential for plant and animal life and constitutes, in impure form, rain, oceans, rivers, lakes, *etc.* It is a neutral substance, an effective solvent for many compounds, and is used as a standard for many physical properties.

**Leaching** –

To leach or leaching is the process

by which components, particles or

aspects of a substance

emit off part of itself into

a new environment.

Leaching is

similar to dissolving but the substance does not dissolve, but rather erodes small microscopic layers of itself into another environment.

With gravel, nutrients leach out

of the rocks and settles in the available water or for plant use.

**Condensation** - The change of the physical state of matter from gaseous phase into

liquid

phase.

Condensation

commonly

occurs

when

a

vapor

is

cooled

and/or

compressed to its saturation limit when the molecular density in the gas phase reaches its maximal threshold. Water is the product of its vapor condensation. Psychrometry measures the rates of condensation from and evaporation into the air moisture at various atmospheric pressures and temperatures.

Many substances are hygroscopic,

meaning they attract water, usually in proportion to the relative humidity or above a critical relative humidity. Such substances include cotton, paper, cellulose, other wood products, sugar, calcium oxide or limestone.

## Gravel Gardening Basics

The most important definitions are those related to sedimentary rocks. The sediment in the word sedimentary relates to organic materials such as dead fish, decayed leaves, wood chips and other sediment that exists in water or is washed out to sea.

Most of the sediment that

creates sedimentary rocks were once organic materials of some sort.

The key aspect of sedimentary rocks is that it leaches or disperses organic materials or nutrients when impacted with water. This rock type which is largely limestone based is also a key element in the living coral reef. In the ocean

limestone based is also a key element in the living coral reef. In the ocean waters, the reef provides life to thousands of species.

The same principal can apply on land.

When sedimentary rock impacts water, a

chemical action occurs where the molecules of the water attaches with the molecules of the rocks to create nutrient enriched water within the gravel.

The gravel itself also acts as a

support system and structure for plant growth. Water enables these “organic” rocks to leach out nutrients capable of supporting root systems for plants and vegetation. Since the origin of the nutrients is a rock material, the rock should leach nutrients for many years.

The rest of the gravel garden configuration is designed to maintain consistent moisture or wet

environment

surrounding

the

sedimentary

rocks

to

create

a

sustainable

root

development ecosystem.



The primary ingredient to control for consistent moisture is the presence of sand under the gravel.

Sand holds and drains water, where soil consumes or absorbs water.

In a gravel garden, sand

is used as

a water storage area beneath the gravel

to maintain a sustained moist environment enough to consistently activate the chemical action between the rocks and water.

The chemical action releases nutrients from the rocks

and

along with water, air and temperature initiates germination.

The submerged sand

allows the water hydrology to be stored and kept cool so that water does not evaporate due to the sun, but rather keep the water available to provide consistent moisture for roots.

We add lawn fabric to the configuration as a layer separating the gravel from the underlying soil.

The fabric not only creates a semi-enclosed environment, but it is also used to spread the water evenly from beneath the gravel.

The fabric also prevents weed growth since it is

layered between the gravel and soil preventing weeds from going anywhere.

When configured properly, the capillary properties within the sand, fabric, and gravel allow the gravel bed to have evenly dispersed moisture. This enables the chemical action to take place and provide consistent feeding of nutrients to root

chemical action to take place and provide consistent feeding of nutrients to root systems. When you water the sand appropriately, you can have a sustained moist environment around the rocks for 7 to 10 days so that root systems can grow and spread out. As water, nutrients, and natural air provide growth support for seeds and roots systems within the gravel beneath the surface, nitrogen fixation and sunlight provide the rest of the ingredients for plant growth and a sustained all natural growing environment above the surface.

## Gravel Gardening Materials

The primary materials needed to build a gravel growing environment are:

1.

**River bottom pea gravel**

2.

**Sand**

3.

**Cotton based lawn fabric**

4.

**Plastic**



The

**pea gravel** should be from rivers, oceans or lakes, generally referred to as ***river pea gravel***.

It should look dirty in nature when originally purchased with sand particles around it.

You should select the river pea gravel that is smallest in size. The sizes range

You should select the river pea gravel that is smallest in size. The sizes range from 3/8 of an inch to 2 to 3 inches.

Buy the 3/8 of an inch river pea gravel when purchasing for your gravel garden.

The larger rocks do work, but the root systems catch better with the smaller river pea gravel.

There are many types of river pea gravel.

During your first year, you should test multiple types of locally available river pea gravel to determine which type works best in your climate.

It only takes 1 to 2 weeks to test the viability of the river pea gravel.

Buy only one bag and see what works against what you are trying to grow.

See photos below of examples of two types of river pea gravel above.

The **sand** should be beach-like sand with tiny particles of rock similar



to what is found on the beach.

This type of sand is common in most locations that sale sand.

Do not, however use powdery sand or sand that sticks to your hand upon touch.

Do not use colored sand.

Sand

is the core of the water storage reservoir used to keep the system moist for a sustained period of time. Since sand retains water instead of absorbing

water

like

dirt

or

soil

does.

the

sand

acts

as

an

underground water storage facility.

The plastic should be plastic rolls . Photo 1 shows an example of plastic in a roll. There are two types of **lawn fabric** needed, the gray industrial type and the black cotton cloth garden type (see photos 2 and 3 below).

The black cloth is referred to as the capillary

fabric as it carries water along the surface of the fabric. The gray fabric will retain water longer so that water is held for use in the gravel gardening system.

Do not use the

plastic based lawn fabrics as they will neither retain nor carry water. Ultimately, the gray industrial fabric retains water while the black lawn fabric carries water to the gravel and eventually to the root systems.



(1)

(2)



(3)



17



## Gravel and Seed Testing

Before

you

go

widespread

with

gravel

gardening,

we

recommend you test a variety of locally available gravel and seed types that you seek to grow.

Once you have a variety of

river pea gravel from available stores, you can test the gravel's effectiveness by using the gravel, sand and an empty clear plastic cup.

Simply puncture a hole in the bottom of the plastic cup.

Fill  $\frac{1}{4}$

of the cup with sand and then gravel.

Pour small seeds on top

to fall through the cracks. Place large seeds in the center of the



gravel. Water to the top and let the water drip into a drip tray.

Refill water when drip tray is dry.

In the three cups below both gravel types seems to have germinated and sustained the seed types picked to test. Beans, corn, wheat grass, broccoli sprouts, micro greens and arugula were tested.

As you can see, the fundamentals are the same, sand on the bottom and gravel on the top.

Once you set up your water bottle tests and drop in a few seeds, it should take about 10 days to determine if the gravel will work with the seeds you are trying to grow.

If they do,

then feel free to set up outdoor gravel gardens.

You should

however only convert a pilot percentage of your space in the first year to determine the full cycle of the crop you are trying to grow. Do not convert everything in year 1.

You can also transplant the sprouts that have germinated in gravel. If you choose to do this however, it is best to transplant to soil versus into another gravel environment.

Roots tend to

be fragile where rocks tend to be hard.

Transplant shock is

likely from rock to rock, where rocks to soil is easier on the emerging root systems.

Wheat grass after 3 weeks.



Micro Greens after 3 weeks.



Arugula after 3 weeks.



Cucumbers after 3 weeks.



19

There are 3 basic layers to a gravel garden system: 1) Top or dry layer which acts as an insulator from the heat; 2) The middle or active moist layer where the seeds and roots are growing; and 3) The bottom layer of sand that is used to keep the system moist

system moist.

Top gravel layer is

dry from the plant

light

heat

or

the

natural sun light.

Middle

layer

or

active

layer of the gravel is moist

from the sand being wet

and is the primary growing





environment.

The

bottom

or

sand

layer

maintains

moisture

in

the

cup while allowing water and

cup while allowing water and oxygen to flow in and out of the cup.

With

some

seed

types,

especially

the really small and tiny seeds, you run the risk of the seeds not making it to the top once the germination process begins.

For small seeds, its

is best to sprinkle on top so that they fall just below the dry layer.

In

this case, these tomato seeds fell a little too low and did not emerge to the top.

They germinated as shown

but the shoots did not make it much farther than what you see here

farther than what you see here.





20

Arvazena (Zena) Clardy Ph.D., Assistant Professor of Horticulture, 4-H SET and NRCS Outreach at

the College of Agriculture, Human and Natural Sciences at Tennessee State University conducted a germination study with her

Plant Science and Floriculture class.

Dr. Clardy

looked at simple germination in cups using Tennessee brown river gravel against 39 different seed types. The basic findings of the study are below.

See chart on page 20 for the types of seeds tested.

1.

**Germination** - Of the 39 experiments conducted, 34 germinated and 29 had emergence and grew to a transplantable state.

All of the seeds that were germinated and the seedlings which emerged had good green color and appeared healthy.

Shoot and Root

systems were well developed with some growing several inches in gravel during the 30

day observation period. See Exhibit A for list of seeds tested in this study. See images of select observations on this and the next page.

2.

**Transplanting** – All of the seeds germinated, seedlings demonstrated good emergence and appeared ready for transplanting as the roots and shoots seemed very healthy and strong.

Given how fragile roots systems are and how hard rocks are, it is best to transplant germinated seedlings from gravel to soil.

3.

**Gravel Depths in Cups** - More shallow depths of gravel tend to do better than deeper depths.

There appears to be an optimal depth for germination and emergence in cups, which is about 2 inches.

There is a specific growing range within the gravel environment where the seeds must germinate and grow properly.

If the seeds fall below that range, then the shoots may likely not reach the surface before dying out.

If the seeds are too

close to the top, they will likely not receive the necessary moisture and water to leach nutrients from the gravel.

Generally, the seed located in the center of the 2 inch range

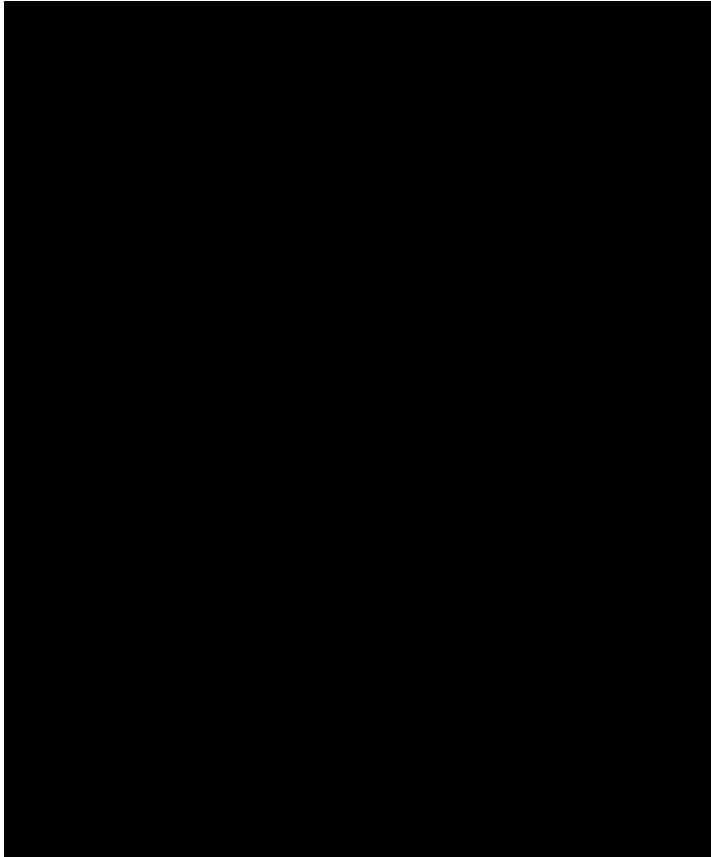
will likely have the best chance of being moist and close enough to the top so that emergence is easier to achieve.

In the taller cup, seed germination occurred consistently as with the shorter cups, shoot development was much less pronounced.

In the taller

cups, the shoots of most of the seeds in the study grew slower than the shoots in the shorter cups.

In the taller cups, the shoots have longer to travel to get to the surface where in the shorter cups the shoots reach the top quicker and develop faster.



TSU student Angela  
Washington growing basil–

photo taken in week 3.

TSU student Amber Lee growing



carnations– photo taken in week 4. 21

**4.**

**Seed Size** - Small tiny seeds should be poured on the top as they can fall to the bottom and not reach the top. This was the case with several small seed types that germinated but did not emerge to the top of the gravel.

Especially in the taller cups, where it was visible

that tiny seeds that germinated made attempts to climb up through the rocks, but could not and ultimately died.

Another alternative to stop small seeds from falling through the

crack and crevices is to put a layer of lawn fabric  $\frac{1}{4}$  to  $\frac{1}{2}$  inch below the top surface of the gravel.

This will allow the tiny seeds to stay close.

A  $\frac{1}{4}$  inch to  $\frac{1}{2}$  inch of gravel on top

should be enough to provide the necessary nutrients to the seeds.

The roots will run

down into the gravel underneath the fabric. For larger seeds, they will stay where they are planted so that they remain in the proper planting area.

5.

**Seed Knowledge** - It is important to read the normal directions of the seeds being planted; some seeds have longer germinating periods than others. So, it is good to set a margin of expectation based on what is already known about the plant variety. Also, some plants do better in the spring, when it may be a little cooler, while others may do better in the hot summer or fall. (Coolseason and Warmseason varieties)

6.

**Watering Schedule** - Watering with gravel is not the same as watering in soil. With gravel it is best to water indoors when the drip cup basin is dry which should be every 6 to 8

days.

Then water once and refill.

The natural effects of the sand seem to help maintain

moisture in the gravel system so that the wet gravel can leach nutrients for the plant root systems.

Some soil based seeds recommend watering every few days.

With gravel,

depending on the seed type, frequent watering can waterlog the seed and kill it.

7.

**Gravel Comparison** – One student compared gravel, to outside soil and potting mix.

The

results concluded gravel grew the five test seeds better than outside soil, but slightly less than the potting mix.

Where seed x may have grown five inches in gravel, it grew 5.5 inches in potting mix.

Although gravel appears to be less impactful than the potting mix, the potting mix has been scientifically enhanced to produce crops.



TSU student Jennifer Williams  
growing spinach – photo taken in

week 2.



TSU student Caroline

Huffines

growing broccoli  
– photo taken in week 3.



TSU student collection of experiments.

Photo taken 3 weeks after seeding.

22

The chart below lists the various experiments conducted by TSU students in Dr. Clardy's Plant Science and Floriculture class.

The chart lists the number of total experiments, the number of

seeds that germinated that grew to a transplantable state, the number of seeds that germinated, the number that emerged, the relative state of the root system and the basic ability to transplant.

The results are sorted by those that were not able to grow to transplantable state first, followed by those that grew, germinating, emerging and growing to a transplantable state.

The results of this test depicts what germinates.

To answer the question of what grows best is

always going to be dependent on your gravel type, seed type and climate.

#

# Germination

Experiments

to transplant

1  
2  
3  
4  
5  
6  
7  
8  
9



9

10

11 1

12 2

13 3

14 4

15 5

16 6

17 7

18 8

19 9

20 10

21 11

22 12

23 13

24 14

25 15

26 16

27 17

28 18

29 19

30 20

31 21

32 22

33 23

34 24

35 25

36 26

37 27

38 28

39 29

Seed Type

Lavender

Lavender - 2

Lettuce

Lima Beans

Moss Rose

Moss Rose - 2

Oregano

Oregano - 2

Rosemary

Viola Tricolor

Alyssum

Basil

Broccoli

Broccoli 2

Carnation

Carrots

Carrots - 2

Carrots - 3

Chives

Chives - 2

Chives - 3

Cucumbers

Garden Beans

Greens

Hot Peppers

Marigolds

Onion

Onion - 2

Parsley

Parsley - 2

Peppers - 2

Pumpkins

Pumpkins - 2

Spinach

Spinach - 2

Squash

Tomatoes

Watermelon

Yellow Flowers

**Ability to**

**Germination**

**Emergence**

**Root Systems**

**Transplant** Yes

Yes

Weak

No

Yes

Yes

Weak

No

No

No

No

No

No

no

No

No

Yes

No

No

No

No

No

No

No

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Developed

Yes 23Yes

Yes

Developed

Yes

This page lists a variety of crops that have been growing in gravel for many years. Gravel tends to do better with legumes and nitrogen fixing plants. Garden variety



vegetables are preferred over spices. Some flowers do well some don't. Bulbs are good, but generally only one time. Only science will tell us why certain crops grow better in gravel than others.

Shading matters: The amount of shade your gravel bed gets will also affect performance. If you have a shaded area, then plant seeds that like the shade. Beans, potatoes and parsley seems to do well in the shade. Most of the seeds on this page do not do well in high shaded areas.

•

Observed in small cups that have been successful:

1.

Wheatgrass

2.

Micro Greens

3.

Broccoli Sprouts

4.

Cucumbers

5.

Tomatoes

6.

Beans

7.

Arugula

8.

Sunflower

•

Observed in small

cups that have NOT

been successful:

1.

Basil

•

Items successfully grown

outdoors in Washington

DC, LA, A, H, I

DC in beige Ace Hardware

KolorScape brand pea

gravel.

1.

Cucumbers

2.

Cherry tomatoes

3.

Tomatoes

4.

Scallions

5.

Lettuce

6.

Spinach

7.

Corn

8.

Squash

9.

Beans

10.

Marigolds

11.

Zinnias

12.

Potatoes

Potatoes

13.

Tulips

14.

Arugula

15.

Parsley

•

Observed in small cups that

have NOT been successful:

1.

Basil

2.

Sunflower

3.

Broccoli

4.

Trees

•

Items successfully

grown in Nashville, TN

outdoors in Tennessee

brown gravel.

1.

Cucumbers

2.

Cherry tomatoes

3.

Tomatoes

4.

Scallions

5.

Onions

6.

Lettuce

7.

Spinach

8.

Corn

9.

Squash

10.

Beans

11.

Greens

12.

Kale

13.

Onions

14.

Garlic

15.

Watermelon  
16.

Strawberries  
17.

Marigolds  
18.

Zinnias  
19.

Azaleas  
20.

Potatoes  
21.

Tulips  
22.

Arugula  
23.

Parsley  
24.

More

•

Observed in small cups  
that have NOT been  
successful:

1.

Trees

## Gravel Testing Tips

1.

There are over 300,000 species of plants and several thousand types of sedimentary rock. There are only 12 types of soil. All 300,000 species have been tested in soil, none in gravel. Test what you plan to grow before going widespread.

2.

Test the various types of river pea gravel in your area against what you plan to grow which respect to crops.

3.

Plastic cups are better than ceramic.

1.

The ceramic holds heat more than plastic and heat the rocks from the sides reducing the ability of the moisture needed to activate the nutrients from the gravel.

4.

For any new place test the area for the best gravel.

I have found the

best gravel in Washington, DC area to come from Ace Hardware, the

KolorScape brand.

5.

After planting, you will notice a top layer that is dry and then a moist layer in the center and then the sand. When you notice the moist layer get dry then water.

6.

Be careful how far down you put the seeds. Do not put too low or they will have a hard time getting through. If you make it too high, it may be in the dry belt

near the surface.

7.

Sand supports the process but so far has not proven to germinate a seed by itself. It is thought that the nutrients from the gravel is enhancing the support in the sand.

8.

Indoor use consumes water at a slightly higher rate than outdoor use, presumably because of the indoor heat and the lamps used indoors.

Because of this, you will need to water twice a week.

9.

Gravel gardening is designed for outdoors. Gravel germinates in cups but the research to date focuses on outdoor gravel gardening.

## Transplanting

On this page, we will walk through the process of transplanting from a small growing area designed to germinate and grow seedlings to individual containers for continued growth.

Below, we see beans that have been growing and producing beans for a few weeks in gravel.

Now we are ready to transplant.

If we leave it, most will ultimately die out. It is best to transplant to an outdoor environment.

You

should

also



have transplant

shock

solution

to dip

the

roots

in

to

help

with

the

transplanting process. Here we did not have those items. Because roots are fragile and rocks are hard, it is likely better to transplant to soil.

To transplant individual seedlings, you first must prepare the destination location.

We are

transplanting into a larger soil based location. There are two transplant options. Option A: Take out loose gravel from the top until you get to the roots. Then squeeze the cup to loosen the sand and gravel.

with soil and water.

is the case below with these multiple bean sprouts.

Pour the entire contents into soil (sand, gravel and roots).

71

Then cover

This method is ideal if your roots are interconnected with other roots as

Option B: Pour out the cup of gravel and carefully disentangle the root system and plant the root sprouts in soil.

This is ideal for those single seed sprouts as is the case with the bean sprout below.

See a visual of this process below.

Despite the transplanting steps below,

gravel gardening is best done outdoors where roots can travel laterally with space restraint.

Option A

Option B

1. Start with your

existing sprouts.



1. Start with your

existing sprouts.



2. Slowly squeeze the entire 3. Stand up gravel sand base in the soil

and cover with the soil.



contents to soil

based destination hole.



2. Slowly squeeze the entire contents out on a flat surface.



3. Carefully  
separate roots.



4. Plant roots 3 to  
4 inches deep and  
cover with soil.



26

## Water Testing

The chart below depicts the water test results for the type of gravel used to grow the cucumbers and tomatoes. Tap water and tap water that has settled in gravel for 10 days were compared and differences were found in the regular tap water and the tap water steeped in gravel.

The results revealed that the gravel removes certain contaminants such as iron, manganese, zinc, and inorganic nitrates making the water cleaner.

There is an increase in

potassium, copper, silica, coliform, and turbidity.  
elements added to the water for root sustainment.  
These items represent the

additional

Potassium, up 23% after 10 days, is the

second most important nutrient needed for plant growth after nitrogen, which already is present due to nitrogen fixation.

Potassium is a key nutrient for the plant's tolerance to

stresses such as cold and heat, drought, wear, and pest problems. Copper, up 18%, is an essential nutrient for plant growth and because only a small amount is needed, it is classified as a micronutrient. Copper is an important component of proteins found in the enzymes that regulate the rate of many biochemical reactions in plants.

Plants would not grow without the presence of these specific enzymes. Research projects show that copper: 1)

promotes seed production and formation; 2) plays an essential role in chlorophyll formation; and 3) is essential for proper enzyme activity.

The silica, up 29%, on

the other hand is not as helpful to plants and it is theorized that this feature may alter the effects of growth, causing the need to test gravel types of the crops you seek to grow before going widespread.

The effects of the added presence of coliform is expected given the sedimentary composition of the rocks.

And finally, the 80% increase in turbidity, which is the

cloudiness or haziness of a fluid caused by individual particles (suspended solids) that are generally invisible to the naked eye, indicates the addition of materials into the water.

The

measurement of turbidity is a key test of water quality and substantiates that the rocks are emitting materials into the water.

These contaminants were detected at or above the minimum detection level, but not above the EPA standards.

All numbers is noted in milligrams per liter

**Contaminant**  
**MICROBIOLOGICALS**

Coliform  
**Regular Tap Water**

0.10 to 1.00

Gravel Sample Difference

% Difference

Effect

Absent

Present\*

0 Not present in tap water

Added

INORGANIC ANALYTES - METALS Calcium

Copper

Iron

Magnesium

Manganese

Potassium

Silica

Sodium

Zinc

48.1

48.5

0.009

0.011

0.025

0

11

9.7

0.005

0

3.6

4.7

5.42

7.61

27

27

0.015

0.004

0.4

1%

0.002

18%

-0.025 Not present in gravel

-1.3

-13%

-0.005 Not present in gravel

1.1

2.19

0

-0.011

23%

29%

0%

-275%

Increased

Increased Removed Lowered

Removed Increased

Increased

Same

Lowered

PHYSICAL FACTORS Alkalinity

Hardness

PH

Total Dissolved Solids

---



Turbidity  
92

90

170

160

7.2

7.9

280

260

0.2

1

-2

-10

0.7

-20

0.8

-2%

-6%

9%

-8%

80%

Lowered

Lowered Increased Lowered Increased

**INORGANIC ANALYTES** Chloride

Fluoride

Nitrate as N

Sulfate

43

39

1.7

0.8

1.4

0

86

69

-4

-0.9

-10%

-113%

-1.4 Not present in gravel

-17

-25%

Lowered

Lowered

Removed Lowered

**ORGANIC ANALYTES - TRIHALOMETHANES** Bromodichloromethane

Chloroform

Total THMs

0.004

0

0.015

0

0.019

0

-0.004 Not present in gravel

-0.015 Not present in gravel

-0.019 Not present in gravel

Removed

Removed

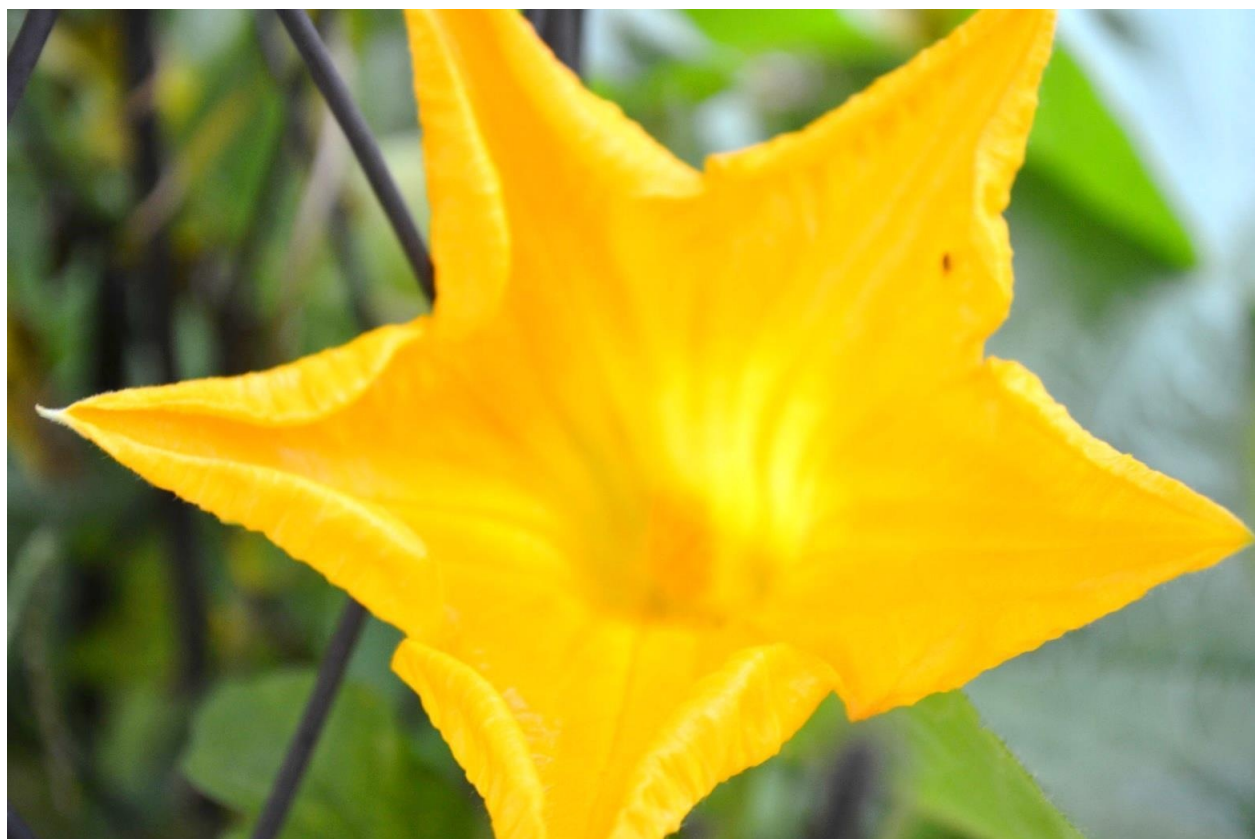
Removed

ORGANIC ANALYTES - VOLATILES Acetone  
0

0.01

0.01 Not present in tap water

Added27\*Above the standard, but not an enforceable EPA action.



# Building Your Gravel Garden

28

There are 6 basic steps in setting up your gravel garden  
(1)

1.

Prepare your site

2.

Digging your trench



3.

Laying your fabric

4.

Laying your sand

5.

Laying the gravel

6.

Planting the seeds

### ***Step 1 – Site preparation.***

Identify the outside area where you plan to have your garden.

The areas should be flat and receive good sunlight for at least 6 hours a day.

You can choose a raised bed or an inground bed as shown in photo (1). Sloped areas are not as effective.

### ***Step 2 – Digging your trench (2)***

Dig

a

6

to

10

inch

deep

trench

along

the

center

of

the

identified garden area.

**The trench should run along the longest side of the garden down the center.**

For example if

you have 3 foot wide by 6 foot long garden space, the trench should be dug along the center of the 6 foot length.

The

trench itself should also be about 6 to 7 inches wide.

See

photo (2).

We measured the 6 inch aspect.

As you see, the

top of the trench tapers off (see photo 3).

This is good as it

allows the sand to flow more evenly across the material.

The

fundamental here is to dig a good trench. You should dig along the longest area of the garden you select.

You can also spray

weed kill on this cleared area to kill off any deep rooted weed roots.<sup>(3)</sup>

The diagram below is similar to the photos, except in the

diagram it shows

the gravel fully underground.

In the photo

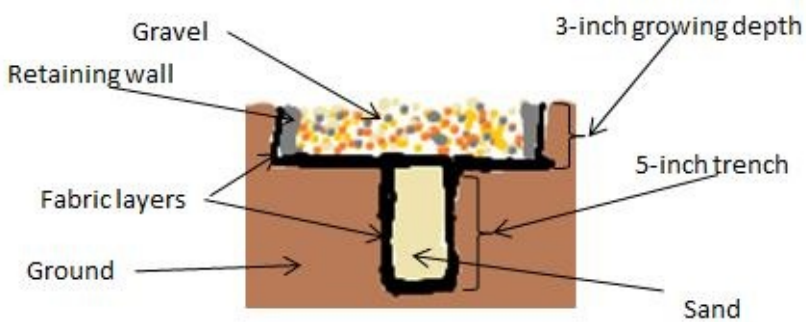
version, we simply added gravel (as you will see on page 14)

and then put up a brick retaining wall.

The illustration is

provided to show a cross section of how it looks underground

with the trench and gravel.



Trench



(3)



29

## More on Trenches

Outdoor gravel gardens require a good sand trench to maintain the proper moisture level so that the gravel's nutrient materials can feed root systems.

Without a proper trench, moisture is not sustained and nutrients are not leached out of the rocks.

You need to also understand that the water that is held in the sand trench can only go so far.

We recommend a maximum of 4 feet on either side of the trench for a sustainable moisture level.

Any longer than 4 feet may cause the moisture to dry up faster, reducing the chances for a sustained moisture level in the gravel.

We

also recommend having a maximum of 6 inches as the water moisture can only travel up the rocks so far. If you do a foot or more of gravel, you will find it difficult to keep the system moist.



Below, we have several shapes which represents a variety of garden shapes with the dimensions listed in feet.

The garden shape is illustrated in brown and the appropriate sand trench configuration is depicted in beige.

In all cases, you lay the two fabric types prior to pouring the sand in the trench.

Remember, the trench represents the water storage reservoir for the gravel garden and that any distance pass 4 feet is too long a distance for the water to travel for a sustainable moisture level.

In some large circular areas you may need to configure the sand trench system in a tick-tack-toe configuration or a circular configuration.

6 Feet

15 Feet20 Feet<sub>15</sub>

20

6 Feet

Garden area

Sand trench

In the 6-foot wide garden, one trench is sufficient as water only needs to travel 3 feet or less on either side of the trench. With the 20 foot circular garden, we recommend

the

grid

like

tick-tack-toe

configuration

to

ensure

moisture

coverage throughout.

In the 15-foot wide garden, you notice two long sand trenches.

This should enable good consistent moisture.

In all cases, when

watering, you want to flood the gravel bed and then the water will receded into the sand trench and stored for future use.

30

### ***Step 3 – Laying the fabric***

Cut enough of both types of lawn fabric so that it covers the entire area.

Lay the gray industrial lawn fabric first so that it covers the entire area and into the trench.

This

fabric retains water longer than the black fabric, but it also eventually allows water to soak through. See photo (1)

Next, lay the black cloth lawn fabric on top of the gray fabric so that the black fabric is in the trench as well. The capillary nature of the black fabric will carry water to

everywhere it is laid. See photo (2)

Although not done here, you can also lay plastic under the fabric to hold the water better.

If you do so, poke a few holes in the plastic, then lay the gray fabric and then the black cotton fabric.

***Step 4 – Pour the sand***

(1)





(2)

Pour sand into the trench so that it completely fills the trench to the top.

Wipe the sand so that it is flat.

Next,

cover the sand with a strip of the black fabric.

The sand

can taper off at the top.

This will allow the capillary

nature of the sand to spread the water more easily onto

the black lawn fabric. See photo (3 & 4)

You may insert the 12 by 2 inch PVC pipe at one end of the sand.

This pipe is what you should water, when watering the gravel garden.

**You do not have to insert the pipe as water can easily flow to the sand with normal watering.** Photo (3 & 4)

The pipe is only when trying to conserve water. In a drought, you can water the pipe only to sustain moisture in the system.

This particular 4 foot by 4 foot version only needs one entry point of water.

If you have a longer area, you will need a new pipe every 6 to 8 feet. If this were 6 feet long, you would put a pipe on either end.

The pipe serves to water the sand which then carries the water anywhere the black lawn fabric is laid. .





(3)



(4)

31

***Step 5 – Pour the gravel***

In this 4-foot by 4-foot space, we sought to lay a 2.5-inch deep bed. This area required 4 bags of gravel weighing 50 pounds each of river pea gravel bought from a local nursery.

See photo

(1)

The pipe shown here is placed directly in the sand. You water the pipe several times until the sand is well saturated. By watering the pipe, you water the sand, which stores the water and

spreads under the pea gravel. See photo (1)

The final step is to spread the gravel evenly over the fabric in the enclosed area.

In this case, we

used a brick border. See photo (2)

(1)







(2)<sub>32</sub>

### ***Step 6 – Plant the seeds***

Next, seed 1 inch deep. In your first year, seed liberally to see how they take to your specific type of gravel.

In photo (1), we planted tomatoes, carrots, cucumbers and broccoli seeds. We seeded halfway between the top of the gravel and the fabric or about an inch deep. With this being our first gravel garden in Washington, DC, it was important to test multiple seed types to see what will work best with this specific type of gravel.

### **Watering**

When you first set up your gravel garden outdoors, water until it floods. You should do this 2 times a week for the first 2 weeks. After that water weekly. If it rains often you shouldn't need to water much.

(1)







## Gravel Gardens in Action

34

As the months went on, we harvested over 100 cucumbers and about 20 tomatoes out of this 4-foot by 4-foot garden.

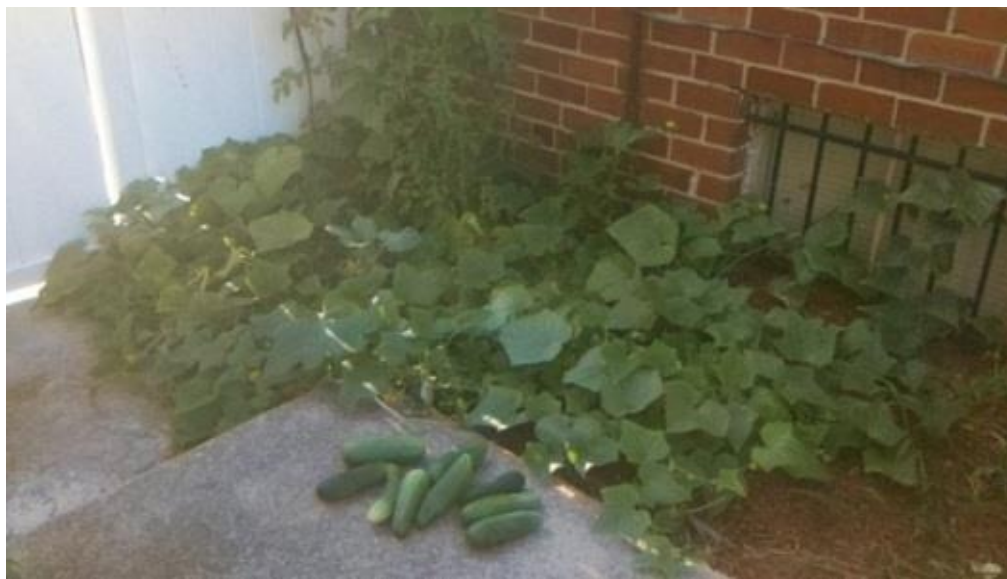
Most of the tomatoes were eaten by squirrels or fell before picking.

The carrots only grew as deep as the gravel or 2.5 inches. Although we did make certain cuts in the fabric to accommodate the carrots, we obviously did not cut in the proper places.

By

September, the cucumbers' vines had begun to decay and decompose back into the gravel, adding organic material and nutrients to the gravel bed which tends to strengthen output the next year. Even worms have begun to find refuge in the gravel, suggesting a good nutrient rich environment.

Since the gravel provides the nutrients, it appears that these tomato roots grew shorter than normal as they do not have to travel as far in seek of food and nutrients.



July 2011



September

2011



December

2011





January 2012



July 2011



October 2011



December

2011



January 2012

35

Here we see what was left over after the winter where we have left over tomato vines remaining in photo A. These you will need to remove by hand. In photo B, you see what is left over and can notice a carrot.

You should clear the debris

and plant new seeds . I also put in another bag of

gravel as I had taken some out over the winter for testing purposes. Photo C represents sprouts

1 month after planting from seed, but it was a cold spring so growth has been slow. Photo D is 2

months after planting from seed.

The scallions on the lower left are doing well, so is the spinach

(down the row in the center) and tomatoes (back wall and right wall).

In photo E, those are

tomatoes that came back from last year.



There are about 15 tomato plants that have sprouted from a standing tomato that fell last November. In photo F, the spinach was ready to cut and was cleaned and put on a plate.

In photo D, the tomatoes on the left wall were planted this year, much smaller than the ones that came back from last year.



**A**



**C**



**E**

**B**





D



F



36

In 2012, an additional space was converted to a gravel garden.

Photo A depicts the original 4 x 4 foot squared on the left, which was featured on the prior slides.

A new 4 x 7 foot gravel garden

was installed in late April.

In photo B, plastic is the primary layer put on top of the ground in the trench. By doing this, the water that is stored in the sand is held longer in the gravel system. Photo C shows the two layers of fabric is place over the area, while photo D illustrates the five bags of sand. Finally, photos E and F highlights the final steps; laying the gravel.





A



**C**



**E**

**B**





D



E



37

In 2012, an additional space was converted to a gravel garden.

Photo A depicts the

original 4 x 4 foot squared on the left, which was featured on the prior slides.

Corn and

cucumbers were planted in the new 4 x 7 foot area in late April.

Photo B, taken in June,

shows the tomatoes, scallions and corn.

Photo C shows the corn near maturity in mid

July.

As the corn died, photo D, taken in September shows the ongoing tomatoes and cucumbers.

Photo C shows photo E illustrates tomatoes still going while the leaves of corn



By late October, photo E illustrates tomatoes still going, while the leaves of corn and cucumbers begin to decay back into the gravel system.

Photo

F, taken in

December depicts the gravel garden at the end of the 2012 season where most of the vegetation has decayed to enrich the gravel garden; somewhat like self composting.



**A**

April 2012



C

July 2012



**E**

October 2012

**B**



June

2012

**D**





September 2012

F



December 2012<sub>38</sub>

In 2013, our home gravel garden is in its 3<sup>rd</sup> year.

As you can see below, good emergence

occurred by early May with the lettuce ready for harvest by early June.

By July the garden's

squash, beans and cucumbers had begun.

Shortly after, the cherry tomatoes came, generating

about 500 cherry tomatoes from July to early November. Pumpkins and watermelons also grew in the gravel garden this year.

You can see additional photos at [www.twitter.com/tosoilless](http://www.twitter.com/tosoilless).

And just like each year, the leaves and vines decay back into the gravel garden.



May 7, 2013





July

8, 2013



October

4, 2013



June 5, 2013



8, 2013

July





November 9, 2013

This school garden was planted on March 15, 2012 (photo E). The spring temperature however has dipped to the 40s at night which is bad for plants especially in gravel.

Plants generally like

the 70s.

Below you will notice that we add a layer of blue plastic.

It is better to lay plastic

under the fabric because it will allow the system to hold water longer (photo C). You should lay plastic over the entire area.

When doing so, poke a few holes (4 to 6) so that some drainage

occurs. Despite the cold, the lettuce is doing pretty well by May 18 (photo H) as shown below.

By May 18<sup>th</sup> the lettuce had been harvested twice (photo G). The other plants don't like the cold so they are small now.

Gravel is not good in the cold because it allows more cold air to

affect the plant roots. These seeds will improve as the weather improves. Follow the progress on these cucumbers, marigolds, corn and lettuce on our twitter.

[www.twitter.com/tosoilless](https://www.twitter.com/tosoilless)



**A<sup>B</sup>**



C



E





G



D



F



H



40

Photo A, taken on May 19 shows the corn coming in. Students had already harvested once by this point. In early June, photo B depicts the corn gaining ground and the marigolds forming on the right.

The lettuce had been harvested five times by mid June.

Also in photo C, you will

notice an expanded gravel garden area. Flowers were planted in this new area.

By mid-July,

the corn and cucumbers are ready to pick as shown in photo C.

Someone even took a bite of

the corn and it was really sweet and juicy.

the corn and cucumbers are still going.

Photo D shows the corn dying out by mid-July, but

By August in photo E, the corn is dead and the

cucumbers have begun fading.

The marigolds and other flowers are doing well.

Up until



October as seen in photo E, the flowers are doing well and a volunteer cherry tomato plant is ready for harvest. You can see a little red tomato on the vine.



A





C



E

B



D



F





The Lowell School gravel garden produced for the kids for the second year in 2013.

We see that

by mid May, the kids are able to eat lettuce snacks in between playing on the playground.

By

July, the summer school camp kids are able to snack on corn and cucumbers while seeing beautiful lilies growing nearby.



April 17, 2013





July 8, 2013



July 3, 2013



May 16, 2013





July 8, 2013



July 3, 2013<sub>42</sub>

## Cucumbers

Below you will see the lifecycle of cucumbers in a 4-foot by 4-foot by 2.5-inch deep gravel garden.

Sprouts start relatively well after about 11 days with the first cucumbers arriving in about 60 days (May 3 to July 2). Other crops were planted and grew in this space (carrots, tomatoes and broccoli) for testing purposes, but the cucumbers dominated. During this period, we only watered 5 times for the entire season.

Although it rained, it was in the mid

90s for most of July and the gravel grown cucumbers thrived while our soil based crops died in the heat. The cucumbers were later tested and the results, listed on page 20, depicts near identical nutrient value as USDA approve cucumbers. Here you see the funnel pipe in the

beginning, but later it was not needed as the rain provided the periodic water

beginning, but later it was not needed as the rain provided the periodic water necessary while the coolness beneath the rocks kept the water stored longer for root growth and sustainment.



Cucumbers

May 14, 2011. 11 days after planting.



Cucumbers,

and tomatoes June 1, 2011.





First

Cucumbers July 2, 2011.



May 14,

2011, the first sprouts can be seen.



Cucumbers June 17, 2011.



Cucumbers still coming August 2, 432011.

In this gravel garden, the dimensions are 2 feet by 4 feet by 1 inch of gravel.

We also used four

types of gravel to compare growth rates between gravel types for lettuce and

marigolds. It took about 10 days to see the first lettuce sprouts, and we had lettuce on the table about 60 days after planting (Mar 27 to May 25).

The marigolds, shown here briefly, are depicted on the following page.

Here, 1 inch

or gravel was able to sustain plant growth.

The trench runs along

the center of the longest side, so it runs 4 feet down the center and about 6 inches deep and 4

inches wide. Type A, C and D gravel came from a national retail chain. Type B gravel came from Tennessee. The Tennessee gravel is the gravel type that we have used most in our 10 year study of this process.

This gravel garden is in Washington, DC.

Grass seed was planted in Type D to

assess grass growth characteristics in gravel. As you can see, the grass is already sprouting well.

As you can see below, type B gravel lettuce is doing better than the other two types.

Type B is

the Tennessee gravel

The variability of gravel types demonstrates that you should test

the

various gravel types in your area before settling on a specific gravel type. Although it seems that type A gravel is less capable than type B gravel, recognize that the cucumbers described in this manual were grown in type A



gravel.

A



**B**

**C**

**D**

New bed with lettuce and  
marigold sprouts April 3, 2011





Lettuce and  
Marigolds May 3, 2011



Lettuce May  
17, 2011



Lettuce sprouts

close up April 10, 2011



Lettuce May 3,

2011





<sup>44</sup>Lettuce May

25, 2011





45

## Tulips

Gravel does well with bulbs as shown below. These photos were taken at Lowell School where kids planted the bulbs in the fall. Unlike bulbs planted in soil that come back each year, bulbs planted in gravel die out after one use.

The primary factors for why gravel is

less sustaining on bulbs than soil are insulation and wildlife.

In soil, bulbs are deep in the

ground and kept at a constant temperature.

In gravel, the cold can freeze out the bulbs.

In cinder blocks the bulbs seem to be insulated enough to complete a full cycle once, but the following year, the bulbs



will not product.

Wildlife also affects bulbs in gravel. We

find that squirrels dig up bulbs in gravel from time to time where in soil this is more difficult. Because of this, they conduct annual bulb planting in the fall with the kids.



A





**D**  
**B**



46

Although planted at the same time, the marigolds ran a later course than the lettuce.

It took

about 60 days for the marigolds to bloom, and during the fall, they were wild and relatively tall marigolds, providing 6 months of marigold blooms for the backyard.

By December when the

first frost started, the marigolds began to die and decompose.

We are harvesting the seeds for

next season.

With gravel, cold has more adverse impact than with soil. With the gravel rocks being open and aired, cold easily passes to freeze plant roots

being open and aired, cold easily passes to freeze plant roots.

In soil, an inch below the surface remains

relatively warm so roots can last longer.

During the first few weeks of December, the

temperature dropped below freezing at night and killed the roots, leading to the drastic change from the height of bloom in November to the decaying process settling in during December.

Despite cold effects, it appears that each gravel type successfully grew marigolds.

There does

seem to be some slight color differences in the marigolds along the 3 gravel types where planted, which suggest that each gravel type may have a different effect on the type of crop grown.

The finer details of the various effects of various gravel types is unknown and is being studied by academic institutions.



April 28,



2011



June 25,

2011



November

17, 2011



2011

May 12,



2011

August 10,





<sup>47</sup> December 14, 2011

In early June, this marigold seems to have returned from last year as shown in photo A.

The

marigolds did not do much and nothing was planted here.

In mid September, gardeners put

mulch over the gravel bed. As seen in photo B, the number of flowers were few. A month later in late October, the marigolds are in full bloom with many bees abuzz depicted in photos C and D.

Photo E shows how much more robust the marigolds grew I one month, but photo F shows how big the marigold blooms grew to before the frost. It appears that the mulch over gravel can be helpful to the gravel gardening ecosystem.



**A**

June 1, 2012



C

October 26, 2012



**E**

October 26, 2012

**B**





September 28, 2012

D



October 26, 2012



F



November 24, 2012<sub>48</sub> In 2013, the marigolds came back naturally for the 3<sup>rd</sup> year in a row.

Seeds from last year fell  
and germinated.

They got up to 4 feet in 2013 but broke after a storm hit.

The bees loved the  
gravel fed marigolds. Mulch is also mixed in this gravel bed.

At the end of the season, over 500  
seed pods were harvested as shown in the final photo.



July 27, 2013





October 6, 2013



October 17, 2013



October 6, 2013





October 6, 2013



January 10, 2014

49

## Nutrition Testing

The cucumbers were tested in a nutrition laboratory and found to be near identical to the USDA standards for a cucumber. The nutrients facts below on the left are from the cucumbers grown in the gravel garden.

As you can see, these cucumbers are good sources of Vitamin A and

Vitamin C with no sodium and low in sugars. The normal cucumber nutrition facts are depicted on the right next to the colored maps.

Notice that the gravel grown cucumbers appear to be more nutritious with more fiber, Vitamin A, C, and Calcium.

There also appears to be more



carbohydrates , dietary fiber, and sugar in the gravel grown cucumbers.



Cucumbers grown

in gravel.

</





Cucumbers grown in soil.

## Nutrition Facts

[Print](#)

[Email a Friend](#)

[How to interpret this](#)

### Cucumber, with peel, raw

Serving size:

[Add to Tracking](#)

[Add to Compare](#)

[Create Recipe](#)

[Add to My Foods](#)

#### FOOD SUMMARY

### Nutrition Facts

Serving Size 52 g

Amount Per Serving

Calories 8      Calories from Fat 0

% Daily Value\*

Total Fat 0g      0%

Saturated Fat 0g      0%

Trans Fat

Cholesterol 0mg      0%

Sodium 1mg      0%

Total Carbohydrate 2g      1%

Dietary Fiber 0g      1%

Sugars 1g

Protein 0g

Vitamin A      1% • Vitamin C      2%

Calcium      1% • Iron      1%

\*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

[NutritionData.com](#)

[Download Printable Label Image](#)

Nutritional Target Map [What is this?](#)



NutritionData's Opinion [What is this?](#)

Weight loss: ★★★★★

Optimum health: ★★★★★

Weight gain: ★☆☆☆☆

**The good:** This food is low in Saturated Fat, and very low in Cholesterol and Sodium. It is also a good source of Vitamin A, Pantothenic Acid, Magnesium, Phosphorus and Manganese, and a very good source of Vitamin C, Vitamin K and Potassium.

Caloric Ratio Pyramid [What is this?](#)



Estimated Glycemic Load  
**1**  
0      250  
Typical target total is 100/day or less  
[What is this?](#)

Inflammation Factor  
**0**  
neutral  
-      0      +  
Typical target net is 50/day or higher  
[What is this?](#)



# Nuances of Gravel Gardening51

## Water Behavior

### Hydrology

- The

scientific

study

of

the

properties,

distribution, and effects of water on the Earth's surface, in

the soil and underlying rocks, and in the atmosphere.

[www.dictionary.com](http://www.dictionary.com).

Hydrology

by

definition

has

several

aspects

that

are

inherent in gravel gardening: 1) water or moisture within the ground on the Earth's surface keeps the sand area cool so that water does not evaporate; 2) retarding water from getting into the atmosphere by holding water in the sand; and 3) interfacing with moisture in the air during the photosynthesis process.

Gravel

and

sand

creates

a

hydrological

system

where

water is conserved by storing the water in the sand and allowing water to be dispersed slowly via capillary actions to the surface. In soil, water escapes faster, especially during droughts which causes the surface of the ground to crack letting water evaporate into the atmosphere.

The

gravel goes a step further and prevents water evaporation,



thus

making

more

of

it

available

for

the

plants'

metabolism and dedicated for root growth.

Generally speaking, water once every 7 days if outdoors and once every 3 to 4 days indoors. When outdoors, the Earth keeps the water cool. The layers of fabric retains the water, so moisture can be consistent. Indoors, the earth is not providing the insulation, so room temperature can affect evaporation to a greater degree.

Planting in pots

can also have similar water issues.

To compensate, simply

create an enclosed sand and gravel growing environment.



This is done easily by lining the pot with plastic.

With gravel the water hydrology allows for a sustained presence of water.

The sun typically reflects off of the rock so that only  $\frac{1}{2}$  inch of the top of the gravel bed is affected by the sun. Underneath the  $\frac{1}{2}$  inch remains moist for days and sometimes weeks without additional watering.

The gravel system allows water to be retained in a sustained fashion.<sup>52</sup>

## **Water Behavior and Heat**



A



**B**





C



**D**

## **Drought-Like**

### **Conditions – At**

the

start

of

drought

period in early July 2012, To Soil Less established a large gravel garden in the middle of open land, planted a few rows of bean and corn seeds but did not water nor fertilize. TSL wanted to figure out what would happen if

you did nothing; no watering, no fertilizer, just open  
100+ degree sun.

By mid-August, both the corn and  
beans had grown about 6 to 10 inches (see photo C)  
and  
by  
mid-October  
a  
small  
crop  
of  
beans  
was  
harvested (see photos D).

Observations reveal that when the initial gravel field  
was installed, planted rows were dug with a shovel as  
shown in photo A.

Photo B on the other had depicts  
what  
was  
happening

just

1.5

inches

beneath

the

surface.

A “condensation effect”, between the rock cooking at 100+ degrees on the outside and the Earth cooling the base of the enclosed gravel structure a few inches below on the inside, created moisture.

Additional experiments found that when you have 100+ degrees on the outside of the gravel, it can be as cool as 75 degrees a few inches down.

The stark difference in temperature results in condensation or moisture being created with the gravel.

Given the results of the corn

and

beans

in

photos

C

and

D,

it

appears

that

the

moisture was enough to sustain plant life for the beans

at least.

Further

test

are

required

in

a

variety

of

high

temperature outdoor environments. The theory that

condensation is created naturally absent of

a water



source can have positive effects on hot climate.

## **Root Behavior**

On the root development side, roots in gravel grow down into and through the sand and bend laterally along the fabric.

The roots also crawl along and attach to the rocks in some cases. In large root systems, you will notice that the roots grow around the gravel entirely. Roots also do well in sand, which is in essence the same as the gravel but smaller.

Below you will see how it works.

First, as with soil, the seed germinates and the roots emerge

and head downwards to the moisture and nutrients. Then the shoots develop and go upwards until they emerge through the surface.

As you see below with the wheatgrass, the roots can

survive closely together in a well geoag ecosystem.

Micro greens after 2 days



Wheatgrass after 2 weeks

Micro greens after 3 days.



Corn after 3 weeks





Micro greens after 10 days





## Root Behavior – Marigolds









This is the marigold roots that was discussed on page 21.

These roots spread out like a web within the 1 inches of pea gravel.

A  
strong  
root  
system

was

was

able

to

develop

within the gravel.

What seems to happen is

that

the

roots

displace

the

gravel

space,

which tends to make the gravel rise slightly

within the garden.

As you can see up close, the roots form

around the rocks in the process.

Other life

also take shelter in this root system such as

small worms and other bugs and critters find

these

micro

micro

nitrogen fixation and adds stability to the  
growing environment. Worms, as you may  
know, digest decaying materials and produce  
soil,  
further  
enriching  
the  
gravel  
growing  
environment.  
roots  
systems.

They  
leave  
behind  
organisms  
which  
further  
affects

This marigold root system grew rather large  
in a 1 inch gravel bed.

gravel

rocks,

they

sources of nutrient material to sustain root  
development.

As it envelopes the

become

embedded

55







## Root Behavior Lettuce

This lettuce root, from the  
lettuce depicted on page 20,  
is  
much  
shorter  
and  
more

more

frail

compared

to

the

marigold

roots.

Still,

the

root

attaches

itself

to

the

rocks as shown.

This rock

helps

sustain

the

root

system

while

constantly

leaching potassium, copper,

and silica into the roots.

Here, a small worm is visible

and likely upset now that I

have

disrupted

its

habitat.

Its

presence

suggests

the

viability

of

the

growing

environment

is

high.

--

We  
have  
seen  
many  
worm,  
slugs, and other critters in  
the  
gravel,  
presumably  
enjoying the gravel as well.

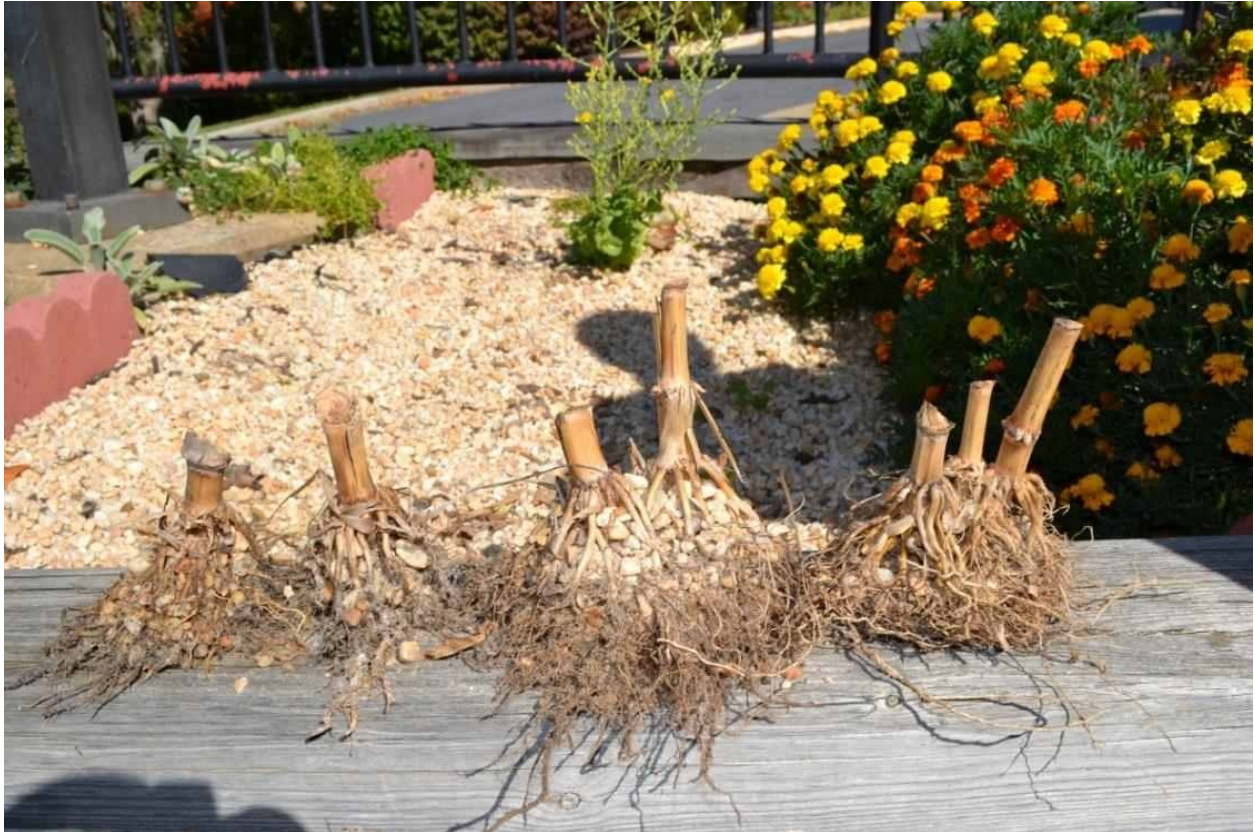
You can also see the sand  
attaching itself to the roots  
as well.

The sand particles  
are basically tiny gravel rocks  
and can provide nutrients in  
the same manner given the  
right conditions.









## Root Behavior Corn

These corn roots were taken  
up  
at  
the  
Lowell  
school  
gravel garden at the end of  
the season.

As you see, the

roots

wrap

themselves

around

the

rocks,

which

helps

sustain

the

root

system.

The

gravel

is

constantly

leaching

potassium, copper, and silica

into the roots to allow for

growth.

When taking up plants and

roots

at

the

end

of

the

season, it is good to shake

out the gravel so that you not

only retain the gravel in the

bed,

but

you

also

benefit

from

the

decay

that

these

specific rocks have with the

root systems.

The rocks that  
are  
in  
closer  
proximity  
to  
direct contact with roots will  
likely  
develop  
layers  
of  
organic decay on the rocks in  
subsequent  
years.

These  
rocks  
or  
enriched  
gravel  
appreciate  
in



organic

material, enabling the gravel

bed to strengthen each year.

Fallen

gravel

direct

better ecosystem of enriched

gravel.

leaves

also

support

appreciation,

but

contact

creates

a

57

**Root Behavior – Scallions**



**A**

These scallion roots look just like the ones sold in grocery stores. The roots appear healthy with good color. Photo A was taken in mid June while photos B and D were taken in mid July.





**B**

**C**



**D**



58

58

## The Grass Cycle





You  
may  
recall  
the  
grass  
seed  
discussed  
on page  
18  
that

that

was

planted late in March 2011.

This

photo

was

taken

in

February

2012. The interesting thing about

this experiment is that the grass is

still visible and green.

The roots

did not freeze and die like the

other plants.

Also, these seeds

were planted in larger rocks, also

from the river.

We don't advise

growing

your

-----

grass

in

gravel

because

cutting

becomes

an

issue.

The rocks would kick up in  
the blades of a mower and cause  
damage. We planted grass to test  
the gravel effect on grass seeds.



As you get closer on the gravel  
you will see how the base of the  
grass  
blade  
comes  
out  
of  
the  
gravel.

You also see a small slug  
hanging out on the gravel.

.

As a  
point of reference, when I planted  
this grass seed  
in gravel, I also  
planted  
grass  
seed  
in  
my  
yard.

The  
gravel  
grown  
grass  
grew  
quicker and thicker.

The roots of the grass on the left  
photo  
seem  
to  
intertwine



together which could explain the





cold resiliency.

You can see new  
grass blades coming out of the  
side

on

the

left

photo.

This

January and February have been

extremely warm where bulbs are

sprouting

early

like

these

grass

blades. If you look closer, you can

see

the

rocks

again

embedded

within the root system.

59

**Gravel Garden Ecosystem**









Adjacent  
the  
rocks  
where  
the  
grass  
is  
growing is a little bug hanging out. Worms,  
slugs, ants, spiders, and all types of bugs

seem to enjoy the riverbased rock.

We do

say that this approach is similar to the coral reef where thousands of species live.

In this

growing environment, the presence of life forms suggest a strong ecological construct suitable for vegetation development.

Although fairly a disgusting sight, this slug is doing

I don't

know

what

on

the

gravel.

Probably sleeping.

Again, another testimony

to the ecological environment provided by the gravel and vegetation.

The broccoli never had a chance with these

broccoli

worms.

As soon

as the broccoli

grew the worms were on them all summer.

This

broccoli

was

planted

with

the

cucumbers discussed on page 16

and 17.

They chew irregular holes in the leaves and

usually

eat

their

way

into

broccoli

heads

heads

from the bottom.

We are not sure where

they came from but they were not there

before

the

broccoli

and

disappeared

after

the broccoli was eaten. Unfortunately, gravel

cannot prevent Mother Nature's presence of

other

animal

life

that can

eat

plants

and

vegetation.

## Gravel Composting

Gravel composting is the process that happens naturally with gravel gardening where at the end of the season, the remaining vines, leaves and left over vegetation decays and decomposes back into the gravel garden.

The theory of gravel composting suggests that the gravel beds appreciate in impact each successive year. During the annual ecological cycle that the gravel garden goes through a variety of composting related activities are underway include worms that find refuge in gravel, the secretions of roots systems, the pollen and leaves that decay and wash away into the gravel bed. All of these elements appear to add organic substance to gravel beds each year.

George Washington University professor Dr. H. Henry Teng of the Department of Chemistry & Environmental Resource Policy Program

in Washington, DC sought to examine the notion

of

accumulated organic matter on gravel used for growing crops versus fresh gravel.

Dr. Teng was

provided a gravel sample that has been producing crops for 20 years and a sample of gravel that has not been used for crop cultivation.

Under a high intensity microscope, Dr. Teng crushed the

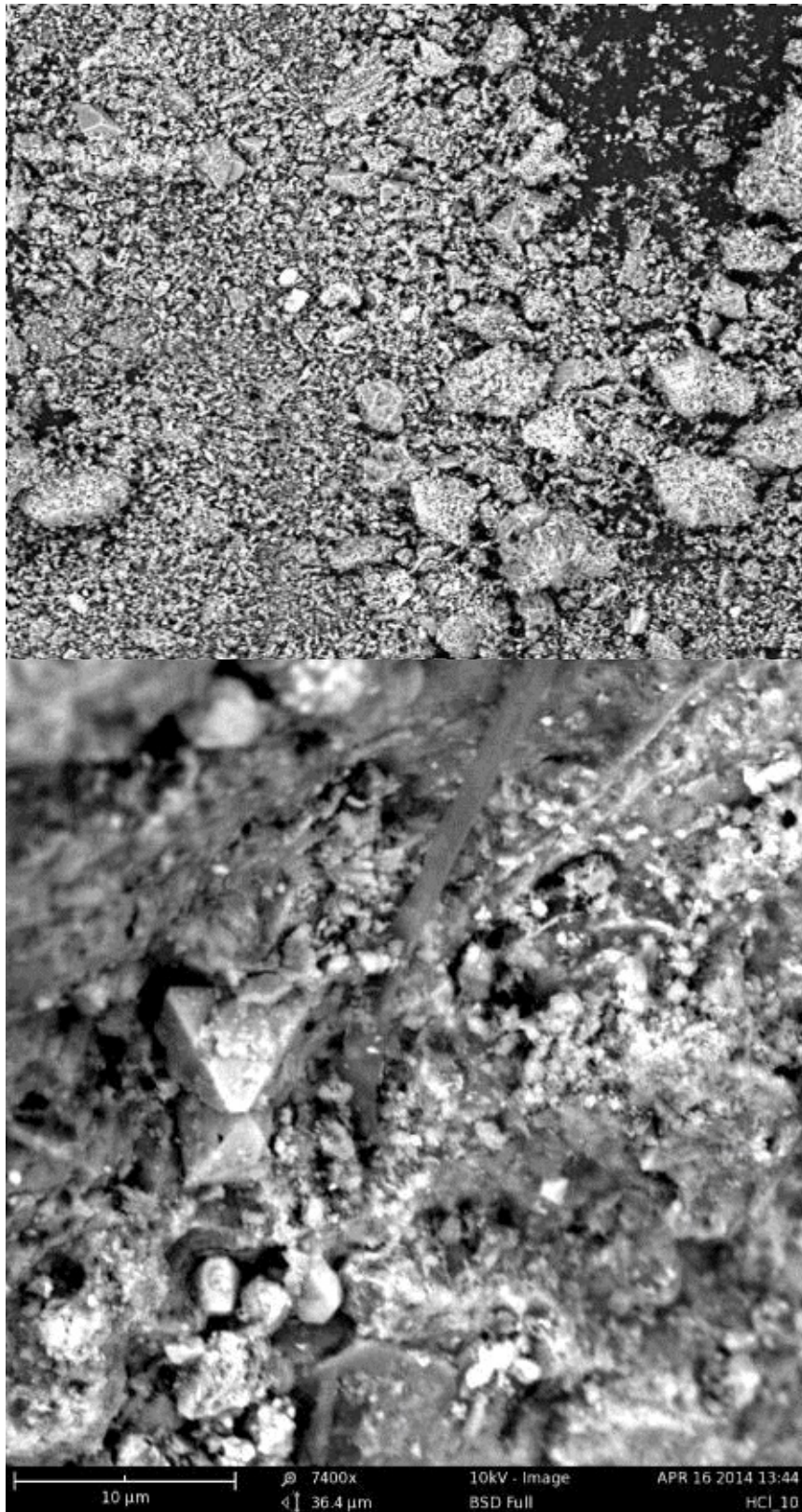
two samples to dust fragments and then looked at the gravel at 7,400 times magnification.

Upon

comparison at this magnification, Dr. Teng noticed a distinct layer of rigid material on the 20 year old gravel surface that was not on the fresh gravel.

The images below depict the rigidity of the 20 year surface at 1,400 times magnification against fresh gravel.





Element

Element

Number

Symbol

14

Si

8

O

6

C

The

fresh

gravel

depicts normal ranges of silicon, oxygen and carbon.

The image

show crushed gravel under the microscope.

Element NameConfidence

Concentration Error

Silicon

100.0

24.3

1.9

Oxygen

100.0

72.0

2.2

Carbon

Manual

3.7

6.0

elemental

composition

is

listed

above

which

Element Number

Element Symbol

8

O  
14

Si  
6

C  
7

N  
20

Ca  
13

Al  
26

Fe  
15

P  
12

Mg  
Element Name

Confidence

Confidence

Concentration Error

Oxygen

100.0

58.7

2.1

Silicon

100.0

10.2

2.4

Carbon

Manual

2.5

4.5

Nitrogen

Manual

7.9

5.0

Calcium

Manual

4.7

5.1

Aluminum

Manual

1.9

7.6

Iron

Manual

11.4

8.1

Phosphorus

Manual

1.2

10.8

Magnesium

Manual

1.5

11.8

The 20 year gravel elemental composition is listed above which depicts a host of elements in varying composite percentages. These materials are basic trace organic elements that have accumulated on the surface of the gravel. The additional elements support the notion that gravel garden accumulate organic material over time.

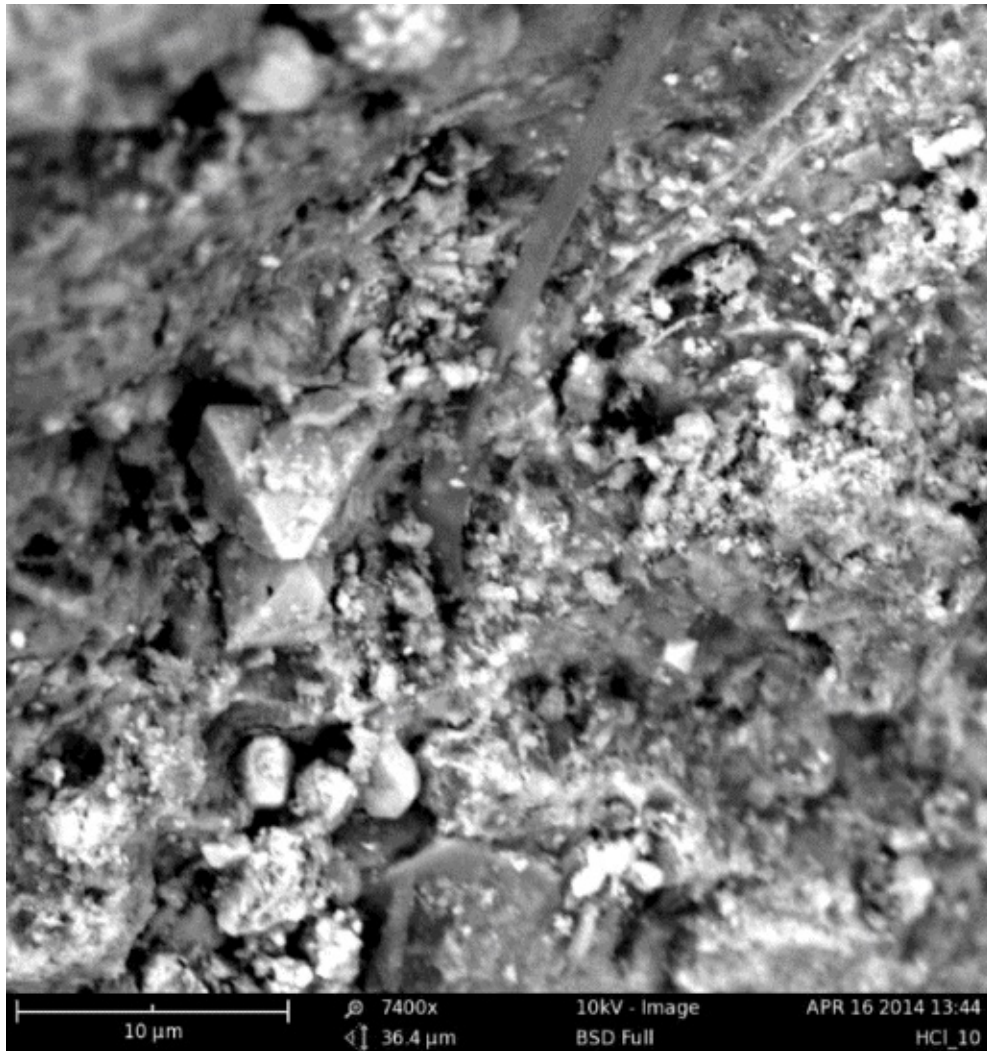
61





The image to the right is magnified 7,400 times and depicts what appears to be root residue on a gravel fragment that has been used for crops cultivation for only 3 years. The pattern of the root residue suggest that the roots are attaching to the rocks for the

apparent nutrients contained in  
the rocks.



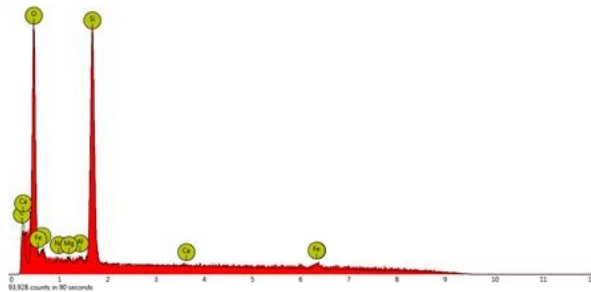
In this version on the 20 year gravel,  
root residue fragments are also  
apparent.

Another key item to point out is the  
pyramid shaped formation on the  
gravel. This suggest geological

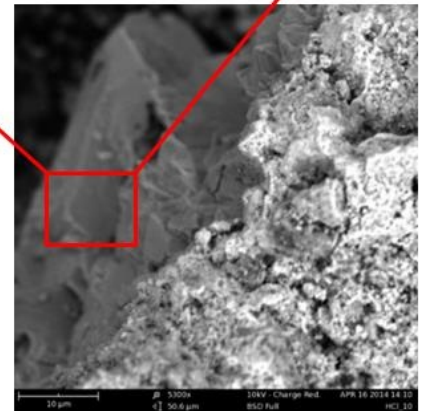
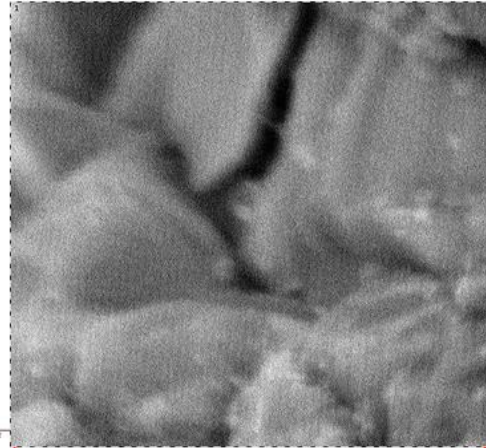
crystallization which occurs during the sediment development process.

62

## Average core composition



| Element Number | Element Symbol | Element Name | Confidence | Concentration | Error |
|----------------|----------------|--------------|------------|---------------|-------|
| 14             | Si             | Silicon      | 100.0      | 22.8          | 0.9   |
| 8              | O              | Oxygen       | 100.0      | 63.7          | 1.0   |
| 6              | C              | Carbon       | Manual     | 2.1           | 3.8   |
| 26             | Fe             | Iron         | Manual     | 7.9           | 6.9   |
| 13             | Al             | Aluminium    | Manual     | 0.9           | 9.3   |
| 11             | Na             | Sodium       | Manual     | 1.5           | 13.0  |
| 12             | Mg             | Magnesium    | Manual     | 0.9           | 12.4  |



The top image is a close up of the image on the lower right side.

The lower

image is 7,400 time magnification of the 20 year old gravel depicting the rough exterior surface from years of decay (rights side) against the inside of the same piece of gravel fragment (left side).

The average composition chart pertains to composition inside the 20 year old gravel.

On the prior page, we provided the

composition of the exterior of 20 year old gravel. On this page will provide the average core composition of the gravel.

As you can see, the core has less

“other” elements than the exterior.

You may also recall that the average composition of fresh gravel was more simple than what is listed here. It is not yet clear why the interior of the 20 year old gravel would have these levels of “other” materials where the fresh gravel did not.

63

## Gravel Composting Academic Findings

Key findings by Dr. Teng in conducting preliminary tests on gravel used for crop cultivation include:

1)

**Gravel Composting** – Gravel that undergoes a cycle of growing crops will likely leave organic material in the gravel garden growing environment.

The organic

materials found on 20 year old gravel was composed of Nitrogen, Calcium, Aluminum,

Iron,

Phosphorus,

and

Magnesium

all

of

which

makes

up

the

components of an accumulated soil like layer of organic matter building slowly on the exterior of the gravel.

Given the nature of gravel, it is likely that

composting naturally occurs with gravel gardens.

2)

### **Gravel Variability –**

In examining two types of

gravel sold in standard

packaging, it is apparent that both types of gravel have 4 to 8 different types of rocks within the gravel.

In the brown Tennessee gravel this is less apparent

because of a brownish coat over the gravel.

But once you look close and wash

away the top layer of dust you find about 6 slightly different rock types and small sea shells. In the Ace Hardware KolorScape gravel, which is beige in color, has about 7 or 8 depending on how you classify the differences. The key notion is to recognize the variability. The key question is to determine which rock does what with respect to plant growth and development. See images below.

3)



**Root Presence** – It is obvious that roots are digging into the gravel in what appears to be specific

root growth formation and patterns.

Root residue was

found on both gravel samples that produced crops.

The root patterns were

consistent with root growth when seeking and finding nutrients.

Given the

microscopic nature of the images, this suggests that the roots may fully wrap around a piece of gravel in its development.

Ace Hardware KolorScape Pea Gravel



Tennessee Brown River Gravel



64

Now that you have a better understanding of the gravel growing method, let us reexamine the advantages to your new gravel garden:

**1.**

**Weeds** – Since we have two layers of fabric underlining the garden bed, inground weeds do not grow.

You will still have airborne weeds, but because of the gravel, they pull up easily.

When pulling any airborne weeds, you can leave the weeds on the gravel and it will decay and add nutrients to the gravel bed.

**2.**

**Deep root vegetation** – For plants like tomatoes that have deep roots, you will need to take a large knife and stab a few cuts in the fabric where you intend to grow your deep root vegetation.

The roots should naturally find  
the opening in the fabric.

You may get weeds through the fabric, but they  
will be focused and easily picked.

**3.**

**The trench** – Feel free to dig a deeper trench. The basic outcome is a larger sand storage space. You can also add organic matter to your trench to serve as natural fertilizers. Refer to page 12 when developing your trench.

**4.**

**Fallen vegetation** – Leaves, sticks, and other airborne vegetation will fall on your gravel garden.

Allow them to decay into the garden.

These natural

elements end up providing natural fertilizers in the growing environment.

The presence adds to nitrogen fixation to assist in plant growth.

**5.**

**Time** – Over time, fallen vegetation, dried root systems (over the winter),

and other natural microorganisms will strengthen the subsequent years growing environments.

Each season, the vegetation will compost and recombine back into the gravel. This should assist with better nitrogen fixation in future years.

**6.**

**Watering** – You really only need to water the outdoor garden once a week to every 10 days, but feel free to water more if you want.

If you would like to

water more and/or use fertilizer, you can expect to have faster growth rates.





65

7.

**Insects and such** – With gravel, you will have less creepy crawly things in your garden area than with soil.

But in nature, there will always be life crawling about.

Fencing,

netting, or doming an area can also prevent passage of insects and such.

Some

vegetation naturally attracts insects, so additional natural remedies are available depending on the crop.

8.

**Funnel pipe** – You can attach any type of funnel system to the pipe. Naturally



having a larger bucket is better as it can hold more water.

You can also have a wider PVC

pipe. Both of these additions will increase the amount of time that overflow water is allowed to saturate the system.

This extends the time that water will impact the

system and increases the level of moisture in the growing environment.

This aspect

generally can lead to a faster growth rate in the plants.

The bucket can also act as a

rain catch basin.

To take advantage of this feature, simply put a layer of cotton (jean thick material) at the top of the pipe in the bottom of the bucket.

The layer of

material will allow rain water to store and will permeate through to the sand over time.

**9.**

**Fertilizers** – Although you do not need fertilizers nor do we encourage the use of fertilizers, one can still add fertilizer and it will undoubtedly increase production.

**10.**

**Maintenance** – Generally speaking, you should not have to ever change the gravel bed.

The rocks will last 100 years and the fabric 20.

You will need to weed airborne

weeds, but actually in this case, those weeds can add nutrients to the growing environment. Therefore, weed as necessary, but leave the weeds to decompose.

**11.**

**Seeding** – In the beginning, seed liberally to see how they do.

As you can see in the

illustrations, it appears that many of the seeds are germinating. You can also seed sparingly as it is still likely that most of the seeds will grow.

When over seeding, one

or

more

of

the

sprouts

may

die,

with

their

decayed

nutrients

supporting

the

remaining plants. You may also need to thin an area if too many seeds germinate. In the beginning, it may take up to 2 weeks before the seeds

germinate. In the beginning, it may take up to 2 weeks before the seeds germinate.





66

12.

**Waterlogged seeds** – From time to time, you may find that in an indoor enclosed pot or recycled water bottle as previously shown, seeds may get waterlogged and die.

You will know if the seed has died when you smell a rotting odor from your gravel garden.

If you smell the odor, you will need to dump the gravel and sand out and start over.

To compensate the next time around, simply water half way

instead of watering to the top. There is a fine line with watering. Most seeds will do well submerged in water, while some may waterlog.

Outdoors this is not an

Outdoors this is not an

issue

as the drainage will keep seeds from waterlogging and the sand will keep the area moist.

**13.**

**Covering** – There are many types of protective products for gardens, feel free to apply any fencing or doming systems as you see necessary for your climate.

Fences

differ

depending

on

the

problem

whether

bugs,

animals,

or

other

elements of nature.

**14.**

**River Bottom Pea gravel** – There are literally thousands of types of water or riverbased pea gravel in the world. All of it should produce the same results; enabling vegetation growth. Some river pea gravel will support growth better than others, depending on a variety of factors to include but not limited to:



1) river, lake, or

ocean from which the gravel originates; 2) geological fault line underlying the rivers,

lakes,

or

ocean;

3)

type

of

life

forms

in

the

water;

and

4)

natural

microorganism reproduction tendencies between one gravel type and the next.

Since the cost of a bag of river pea gravel is cheap enough to test several types, one should do so.

If all produce the same in output, go with the gravel type that

you like best visually.

you are not ready.

15.

**Portability** – Although the system requires set up, it is also completely portable.

Neither rock or sand will decay in your lifetime, so you can always relocate your gravel garden.

or dormant.

expectations.

relocate.

If you do, it is best to do so in the winter when everything is dead

At this point, mixing up the gravel will not affect your growing

Simply put the gravel and sand in sturdy bags or containers and





67

16.

**Green** – Gravel gardening may represent the most efficient use of nature to provide food for people. Gravel and sand are organic and sustainable by nature. This approach eliminates soil degradation, fertilizer contamination, and soil consumption. Gravel gardens reduces weeds, water requirements, and cost to garden. This method uses materials that are in abundance on the planet.

17.

**Organic** – We have consulted the organic certifiers and they tend to feel that this method of gardening can be certified as organic for growers who choose to go through the organic certification process. They also indicate that a method in of itself is not certifiable because someone who uses gravel as the growing medium may still do or add something else which may make it non organic. Each growing operation has to go through the organic certification process to be listed a organic. If you seek to label your operation as grown in gravel as organically

certified, this method would possibly be the organic test.

**18.**

**Planting** – Should you want to plant other plants from your local nursery that are already

in dirt or soil, you are able to do so. Simply make sure you have enough depth and treat the gravel like dirt and transplant from the pot to the gravel and water. The irrigation system will also impact the dirt allowing for a sustained and moist environment within the soil.

**19.**

**Integrating Soil** – If you choose, you can mix soil within the gravel. We have done this to determine growth effectiveness and found that soil that is mixed with gravel tends to provide robust growing environments without adding fertilizers. The irrigation principals apply so the vegetation can still be robust.

**20.**

**Harvesting**– Be careful when picking your crop from a gravel garden. The looseness of the gravel means you have to make sure you don't pull the roots, unless you choose to do so. For most harvesting, we recommend cutting or pruning versus pulling. You can easily de-root a plant.

**21.**

**Troubleshooting** – If the system is not working, here are the likely causes:

–

Not enough water at the onset - fix by watering;

–

The gravel is too deep and the water cannot sustain moisture – fix by using less gravel or configure in a completely enclosed environment so that the area stays somewhat submerged in water;

–

The lawn fabrics doesn't appear to retain the water – fix by doubling up the

layers of lawn fabric and or add a layer of plastic under the lawn fabric. If you add the plastic, punch a few holes in the plastic so that you have some drainage taking place.

---

Waterlogged seeds in an indoor pot – fix by making sure some drainage occurs or water half way. You will need to empty the pot and start over, especially if you smell a rotten odor.









# Additional Gravel

## Configurations

69

### Alternative Usage Overview

Welcome to the community side of gravel gardening.

Before we begin, we are home gardeners

not community growers.

Therefore the community applications represents what we would recommend to community users given our 15 years of growing and experimenting with gravel gardening configurations.

In this context, we are narrowing our commercial discussion to greenhouses,

community gardens and

small farms.

Large scale

farming can

adapt

these

methods, but should test on a small scale initially, before going widespread.

The testing of the

gravel types against what you are trying to grow specifically is critical to success in community gravel applications.

You have seen the basic of gravel gardening now it is time to share community application of the gravel gardening method of agriculture.

The materials are basically the same but in larger quantities.

The rest of the community equation is configuration according to the specific product being grown.

Obviously with community applications, cost are higher such as land preparation, materials, and watering.

The primary community applications that we will discuss are:

- Greenhouse
- Flower Beds
- Small Farm
- Rooftop Gardens



70

## Alternative Configuration Materials

### Gravel

Sourcing gravel for commercial applications require developing a relationship with a gravel supply company. You should research the various gravel supply companies in a 50 mile radius and obtain a sample of each of the river pea gravel.

If they have multiple sizes,

request to sample the smallest size river bottom pea gravel.

You will find that when you

purchase gravel from a gravel supply company that gravel can cost from \$20 to \$30 per ton, which can be enough gravel for many greenhouses and some community gardens.

River pea gravel is typically used as an construction ingredient and as decorative



rocks in

landscaping, so the supply of gravel should be adequate for most commercial applications.

### **Sand**

Wholesale sand is easy to source locally and you should have no problem obtaining sand.

Most locally available sand will suffice.

### **Fabric**

Most of the industrial and residential lawn fabrics come in large roles.

You can easily find

the proper lawn fabric in the garden section of any nursery or garden products retailer or at your local gardening store in increments of 25, 50 or 100 feet.

### **Hay**

On cement, gravel gardens burn up from the heat of the cement on a hot day. One of the key necessities for gravel gardens is that the bottom or underbelly of the gravel garden remains cool. Because of this a bale of hay is an option. You would cut into the hay about 6

inches deep in a desired growing square or rectangle.

across the entire area.

Put about 2 to 3 inches of sand.

Seed and watch.

Lay plastic, lawn fabric and sand

Add a layer of fabric and gravel.

### **Cinder Blocks**

Cinder blocks are ideal barriers for large gravel beds.

In most of our cinder block activity,

the holes of the cinder blocks are serve as additional growing areas.

Cinder block gravel

gardens have proven to grow bulbs well.

### **Risers and Insulation**

When attempting to set up gravel gardens off of the cement, a variety of creative options are available.

The follow pages depict basic crude approaches to elevating a gravel garden on cement.

### **Greenhouses Containers – Cup O Gravel**

In greenhouse environments you will need to consider your own personal operation and how to adapt using gravel and sand.

You will also need to consider your transplanting or harvesting needs.

By in large, you will place your seed in small containers and grow them to a certain height, usually under a foot for most items.

**Configuration** – In the container you select, you are simply putting an inch or two layer of sand and then gravel.

Since the area is small and enclosed, water should spread evenly, and since weeds are not present, you don't need the fabric.

The below photos depict examples of the

depths to plant at in a small container and placing them in rows. You can also configure in tubs and other containers as shown in the transplant section. Be sure to plant in drainable containers.

Below we have basil, cosmos, garlic, cucumbers, organic greens, wheatgrass and broccoli spouts in recycled bottled water.





**Watering** – Depending on the temperature in the greenhouse, you could find yourself watering every 3 to 4 days if not daily.

At home, I find myself watering the mica daily, while the gravel consumes the water every 3 days, which is different than outdoors.

At home, this is the case

because it's the winter and the house is at 65 to 80 degrees all day. When watering, you should be able to shake the water bottle and see water just above the sand. Because the water can dry out faster, you want to keep it watered regularly.

Fortunately, you only need a few tablespoons

of water. A spray can also do the trick. You don't want to water past half way of the gravel as to not run the risk of drowning.

In our experience even if you do water high, the plant ends up

consuming all of it. You will need to poke holes right above the sand or on the bottom so that the standing water will drain. Do not keep in a completely enclosed container.

**Transplanting** – With transplanting, you will need to determine your requirements.

If you want

to transplant your crops to the soil, then we recommend using biodegradable containers instead of the plastic water bottles.

If you plan on putting your plants in another pot, you may want to

consider lining the container with a plastic bag that you can pull out and cut when ready.

See

transplanting section.

In the large photo here, you see how the roots behave for this cosmos flower plant. You can actually pull the roots out bare root as well if you transplant



immediately.





Here  
we  
have  
Swiss  
chard  
and  
iceberg  
lettuce growing in trash cans that are lined  
with plastic. We conserve water by putting a  
funnel pipe directly to the sand.  
At small  
home gardens you can water easily.  
When

you have large planting spaces, you can save water by directly watering the funnel pipes.

Here the gravel is about 3 inches deep, with the sand 6 inches deep and soil filler at the bottom.

The plastic is placed over the soil but under the sand and gravel.

Here we have a 20 foot by 8 foot by 4 inch deep gravel.

The trench runs along the

center of the 20 foot line so that the water feeding distance between the trench and the edge of the bed is 4 feet on either side.

Here we have green beans growing on the fence as shown.

With this configuration,

water is added through the funnel pipe as shown in the garbage can version above.

These photos were taken in August 2010 so the beans have already peaked.

In this large 20-foot circular gravel garden, we have asparagus and elephant ear plants growing.

You see the water hose here.

This  
was done to make it easier to water. Simply  
place the hoses appropriately and water as  
necessary. When constructing a bed of this  
type, one needs to dig trenches in a grid  
format  
or  
a  
circular  
format  
so  
that  
the

trench is dug in a way that allows the water to only have to go 4 feet in either direction.

(see page 12) .

With asparagus roots, you need to place them in the sand trench, then add about 3 inches of gravel.

We have fencing around this bed to protect against local wildlife.







Here we have a 10-foot by 10-foot raised bed with cinder blocks as the barrier and a protective fencing.

You can use any type of barrier, as most use wood or plastic barriers to raise the bed. In a similar

fashion with raised bed, you create the area, dig the trench either the single long row or grid, lay the plastic, then fabric, and then pour the sand and add the gravel.

The use of cinder blocks make the structure durable.

This gravel bed was constructed in 1998. This photo of what is left of this years strawberries was taken in 2010.

In this gravel garden, we have not changed the bed nor gravel in 12 years and have never added fertilizers.

Cinder blocks can also be used as planting pods as well where you line the bottom of the space with the plastic, then fabric,

then sand, and finally gravel.

Here we

have Swiss Chard growing.

You can also

see

the

PVC

funnel

pipe

used

in

this

instance

to

provide

water

to

the

sand

trench beneath the gravel. The raised bed

is 8-feet by 12-feet.

This bed is actually  
on a platform.

With this type, you add 6  
to 10 inches of dirt on the base before  
laying the fabric.

The addition dirt allows  
the trench to exist above ground.

This is  
done to create a large bowl effect so there  
is little water loss.

These golden squash leaves are climbing  
up the fencing.

This 6-foot by 10-foot  
gravel bed was constructed in 1999, with  
these

photos

of

the

2010

crop.

Incidentally,



this

was

after

a

55

day

drought in Nashville, TN, the location of  
this gravel garden.

Despite the lack of

rain, the underground capillary watering  
system

kept

the

gravel

cool

and

moist

throughout the drought.

In this case, the

funnel

pipe

was  
critical  
to  
the  
large  
planting operation to conserve water.<sup>74</sup>





In this section of the gardening area we have several 6-foot by 6-foot raised and in ground gravel beds, growing strawberries.

It is

important

to

measure

the

proper

length of the piping portion of the funnel  
pipe.

This particular funnel pipe is 1.5  
inches in diameter and 5 feet long.

We

use

the

red

buckets

for

collecting

clean water from the kitchen, rain, and for  
random organics such as leaves.

Here we have

purple sedum in geometric

concrete stepping stones in rows

concrete stepping stones in rows.

Each

purple sedum is growing in individual inground, 2 by 2-foot gravel pods.

We dig

down 5-inches in the 2-inch by 2-inch area.

We then dig the trench.

Next we lay the

plastic, lay the fabric, pour the sand, cover

the sand, and pour the gravel.

The purple

sedum here were planted from

saplings

and not from seed.

They were planted

from dirt and the dirt around the roots

were placed in the gravel.

Dirt mixes well

with gravel, since dirt is defined as crushed

rock. The gravel itself is 5-inches deep.

75

**Community Gardens: Conserving Water**



To conserve water with gravel gardening, you can, and should in some cases, insert a PVC pipe to the sand and add a funnel to the top of the pipe as shown in the photo to create a “funnel pipe.”

This funnel pipe watering method allows you to conserve water as you only need to fill the funnel 2 or 3 times in a given in ten minute period every 7 to 10 days.

You want to wait 10 minutes as

that is how long it may take for the water to drain into the sand.

You can also add natural

materials in the funnel like roots, plant life, and lichen. These items (natural fertilizers) will assist with nitrogen fixation within the water that then passes down the tube to the sand and ultimately to the gravel and root systems.

Since the containers are lined with plastic, the water is held for the plants.

In the photos below, we use recycled water bottles as the funnel.

On the left, the funnel pipe

watering method is supplying water to the sand to feed jalapeno peppers.

On the right, the

funnel pipe is watering strawberries that are also enclosed in a protective fencing so the local birds don't have our strawberries for lunch. The natural materials within the funnel also acts as a barrier which allows rain water to accumulate and slowly seep into the system. After a good rain, you can sometimes see water still in the funnel for a day or so.

Because the sand is full, the

funnel pipe allows for additional water storage until the sand depletes water into the capillary system to the gravel.





## Gravel Gardening on Cement

“Can gravel gardens do well on cement?” is a common question posed when considering urban applications for geological agriculture. The answer is both yes and no. The underbelly of the gravel garden must be kept cool for the geoag ecosystem to function properly. The Earth provides a natural cooling base for the gravel garden which 1) helps keep water in the system longer and 2) enables trace condensation to occur on really hot days.

If you want to configure a gravel garden on a rooftop, deck or cement patio, you will have to elevate the gravel so that the underbelly of the geoag ecosystem remains cool on hot days.

There are a variety of ways to accomplish this goal. On the following page, a crude method was arranged using recycled materials called the mattress gravel garden.

You can set up a gravel garden inside a bale of hay, on top of a table or on top of a pile leaves. In all cases, the underbelly of the gravel bed must be kept cool. So here the answer is yes.

Cement can heat up to 100 degrees and burn everything from beneath in one day. Never construct a gravel garden directly on cement. If you do it this way, the answer is no.





77

The image to the right is a raised gravel garden on an old mattress.

The lining of an SUV hatchback serves as the basic “container” of the gravel bed.

A layer of plastic was laid.

An inch of sand was spread evenly on the entire area and lawn fabric covered the sand.



2 inches of gravel was poured on  
the fabric and seeds planted.

Tomatoes, beans, cucumbers and  
zinnias were planted



The beans and zinnia made it to  
full

term

and

harvest.

The  
tomatoes in the back developed  
some but only produce 1 cherry  
tomato.

11/11/2023 11:11:11

The cucumbers started  
but did not finish.

In the ground  
based gravel bed, the tomatoes  
did really well during the same  
period.

This is not ideal but it  
does demonstrate that elevating  
gravel

on

cement

is  
recommended.

The heat of the  
summer did not burn the bottom  
of

the

gravel

bed

this

time  
around.



The beans grew to  
full term in gravel  
on the mattress.



The zinnias  
bloomed in gravel  
on the mattress.





79

## Hay Gravel Gardens

Bales of hay have been used as a medium for outdoor crop containers for a while. See examples of soil growing crops in hay containers.

We have not tried to use hay as a growing base for gravel gardening but will be doing so during the summer of 2014. Look to our twitter @ToSoilLess to see it in action during the summer.

When we construct the gravel garden in hay, we will:

- 1.

Cut out the center of the hay so that it goes about 4 to 6 inches deep, wide and a good size long.

- 2.

Remove excess hay so that you have a rectangle or square box cut out inside the hay.



3.

Line the bottom of the hay with plastic and puncture a few holes in the plastic.

Be sure the plastic goes up the sides of the hole cut in the hay. We want to create a bowl effect but puncture for air.

4.

Line the plastic with lawn fabric.

5.

Pour 1 to 2 inches of sand so that the entire based is covered evenly.

6.

Put a layer of lawn fabric over the sand.

7.

Pour gravel in to the top.

8.

Seed and water.

## Gravel Garden Roofs

- 

Green roofs are nothing new

- 

Society has experimented with elaborate and simple expressions of green roofs for decades

- 

Gravel gardening is simply another item to consider in green roof design

- 

The weight and space is comparable to existing formats of engineering

- 

The difference with gravel green roofs is to insulate the roof in a manner that

The difference with gravel green roofs is to insulate the roof in a manner that keeps the underbelly of the gravel garden cool

- 

On hot days the sun heats the roof and causes the underbelly to heat up as well, killing any vegetation in the gravel garden

- 

The gravel garden is designed to repel heat from above not below

- 

A special foam layer is needed under the gravel to protect it from the hot roof

- 

Alternatives also include raising the entire bed off of the roof, enclosing in custom drainable insulated flower boxes or other creative ways to reduce the impact of heat related to the roof

- 

There are 12 types of natural soil on the Earth, but there are thousands of types of sedimentary rock

- 

All sedimentary rocks are different in composition

- 

Consequently, testing is needed in every city independent of any other city

- 

In Washington, DC, of all the available gravel, Ace Hardware KolorScape brand has the best and most effective for growing crops

- 

In every city, the best source of gravel for the specific climate of the city must be determined before consumer or commercial use

## Gravel Garden Roof Design

There

are

a

variety

of

layers

already

embedded

in

the

design

of

most

green

roofs

Why are Gravel Gardens Good for

Building Design?

As

shown

here,

all

have

some

sort

of

insulation, water proof membrane *etc.*  
Custom design for roofs, patios,

decks and indoor lobby areas

With gravel gardens a layer of sand about 3  
inches deep and a layer of gravel about 4  
inches deep replaces the current growing

medium

Attractive to consumers and

guests

Durable and practical

The key components of a well designed roof

top gravel garden is properly tested gravel

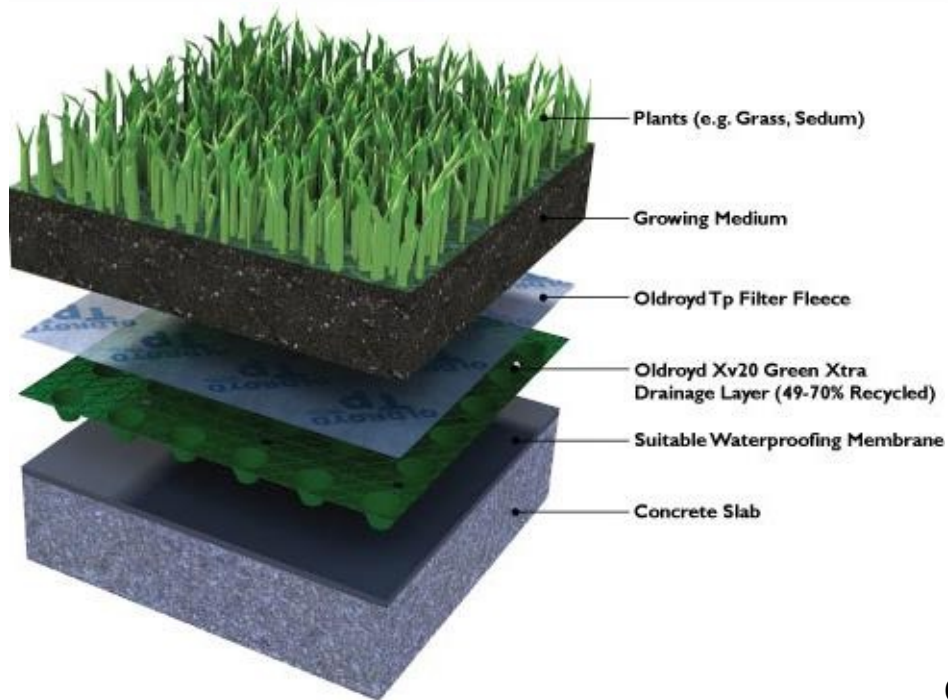
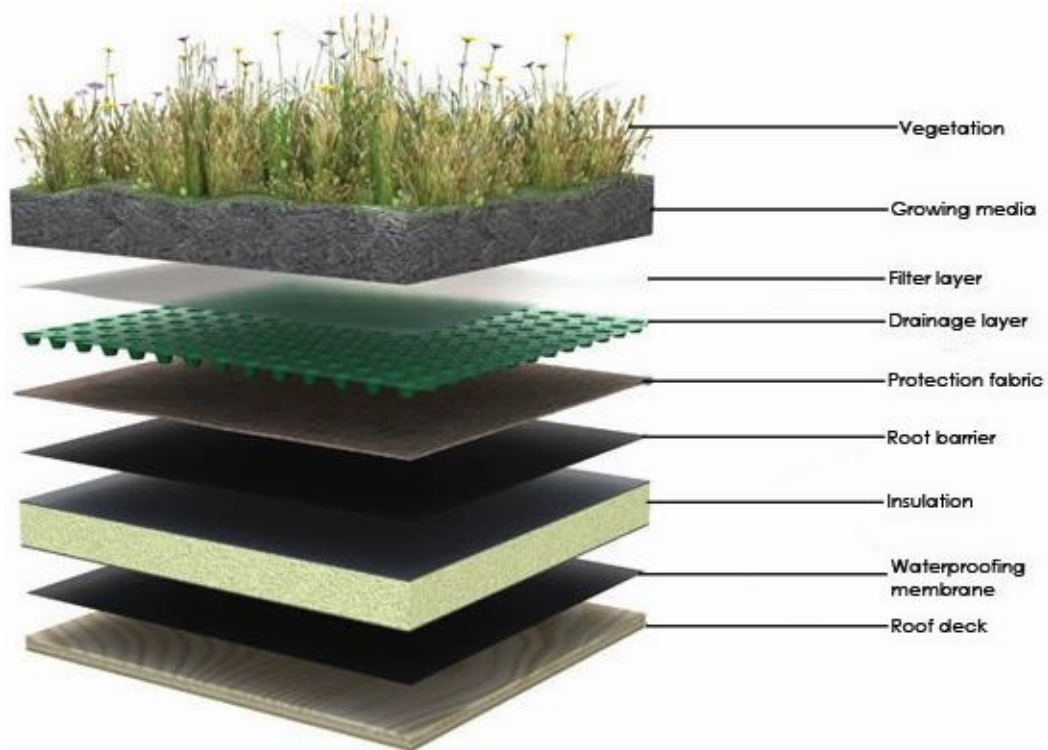
and properly insulating the bed from the

heat of the roof

Once tested, you will plant what

has been tested to do well in that

gravel type



Custom low cost

irrigation integrated into the design

Low cost materials as river pea



gravel is already a construction

material often used

All images taken from Google search of  
rooftop gardens.



82

## Gravel Farms

With row farms, you can water several ways. You can insert funnel pipes every 10 feet. When it rains, you will capture water and will enable water to be stored and used for longer periods of time.

If you have pre-existing irrigation equipment, you can place the water outlets near the sand.

At the ends of the rows, you can have your water sources feed the end of the sand row on both sides. It will take 10 minutes to 20 minutes depending on how long your planting rows are.

If you have long irrigation hoses, you can also place the hoses within the sand as well and supply water via your hosing system.

You will need to keep your tractor row mowed so that you can walk through the farming area and reduce the chances of weed spores floating into the gravel.

This method will reduce the chances of you having to weed as much.

Also be careful when harvesting with a tractor as the rocks can get kicked up into the tractor equipment inner workings.

Although gravel applications can be good for commercial farms, the national supply of gravel is not yet suited for a widespread use of gravel in agriculture by large farmers.

Home and community garden demand is suitable to current river gravel supply.

Large farms are not.

Large farms should only do this on a limited basis and only in States that have large gravel supplies that will not disrupt environmental necessities.

As previously mentioned, all applications of commercial gravel activity should be tested on a limited basis in year 1 for the specific type of crop being planted.

Retrofitting an acre of land

into gravel rows is estimated to cost about \$5,000 an acre or more. So you want to be sure the crop you seek to grow does exactly what you want it to do in gravel and completes a full lifecycle before investing large amounts to retrofit our land.

## **Small Farms**

Large scale farming with gravel can be accomplished with gravel rows.

The depth of the

gravel row will depend on what you want to grow. As with most farming, try to farm on land that is flat, although slightly sloped is ok as well. With gravel rows, you want to space apart 3-foot lines where you have a 3-foot planting row and a 3-foot tractor or walking row. This if is you want to harvest using a tractor or manually.

Next you have to dig the necessary trench along the center of the planting row.

If you do

this process manually, then keep the lines down.

If you use a tractor with the necessary

attachment you will need to remove the lines so the lines don't get entangled in the tractor.

Dig the trench to be about 10 to 12 inches deep.

This is done to help minimize

watering where a good rain could keep it watered longer.

Also, the depth is ideal for

natural durability of the system.

natural durability of the system.

inches as well.

This will make is so that you don't have to necessarily include a retaining wall. You can have a retaining wall if you want especially for inground crops that requires more of an air tight system.

When laying the fabric, crop fruit development is important.

For crops that fruit above

ground, you can lay the industrial and then the capillary fabric and keep the

ground, you can lay the industrial and then the capillary fabric and keep the depth at 3 to

4 inches.

For crops that grow below ground and you need a deeper depth maybe 10

inches, then you need to lay plastic first followed by the industrial and finally the capillary material.

With inground fruiting crops, your initial trench should be 12-inches below the 10-inch. See diagram below and photos on the next page.

Gravel 3-inch growing depth

Retaining wall



12-inch trench

Fabric layers

Ground

Sand

Dig

Lay materials

Benefit



84 Tractor row

Tractor row

**Field Gravel Garden**

The first step is to flatten an area and dig a trench as shown in photo A. The trench was dug with a back hoe and the sides are being flattened by a bull dozer. Next lay plastic as shown in photo B.

Be sure to fasten in the ground along the trench. Photo C depicts laying the layer of black fabric.

Because the plastic was thick, we did not have a layer of industrial fabric. Photo D shows were sand was placed in the trench and photo E shows the sand after covered with fabric.

Gravel is

being poured in photos F and G. The 125 foot by 12 foot field gravel garden is complete in photo H. See the before and after on the next slide.



**A**





C



**E**



**G**

**B**





D



F





H



85

**Beans and corn planted July 1**



**Photo taken**

**August 18 after**

**40 days of 100+**

**degrees an no**

**manual**

**watering.**





86

86

**Harvested October 18<sup>th</sup> with no manual watering during low rain period, enabling a second season of harvest.**







**Beans picked on October 18<sup>th</sup>, they could have been picked earlier but know one**

**was monitoring this field.<sup>87</sup>**

Going soilless with gravel gardening can have global implications as for the first time, one can go to the beach or river in a forest and make a sustainable vegetable producing garden with nothing but the shirt on your back.

Survival gravel garden steps at a beach or forest river:

1.

As you have already seen, the primary ingredients for gravel gardens are sand, rocks from water, and capillary material.

2.

With your shirt serving as the capillary material, one can take sand and gravel from the beach or river bed and create a gravel garden. The nature of the beach

or river will determine how long you have to search for rocks.

3.

Once you gather your rocks from the ocean or river, be sure to break the rocks into small gravel size pieces. Use a big rock to break rocks and shells into gravel size pieces as shown in this manual.

4.

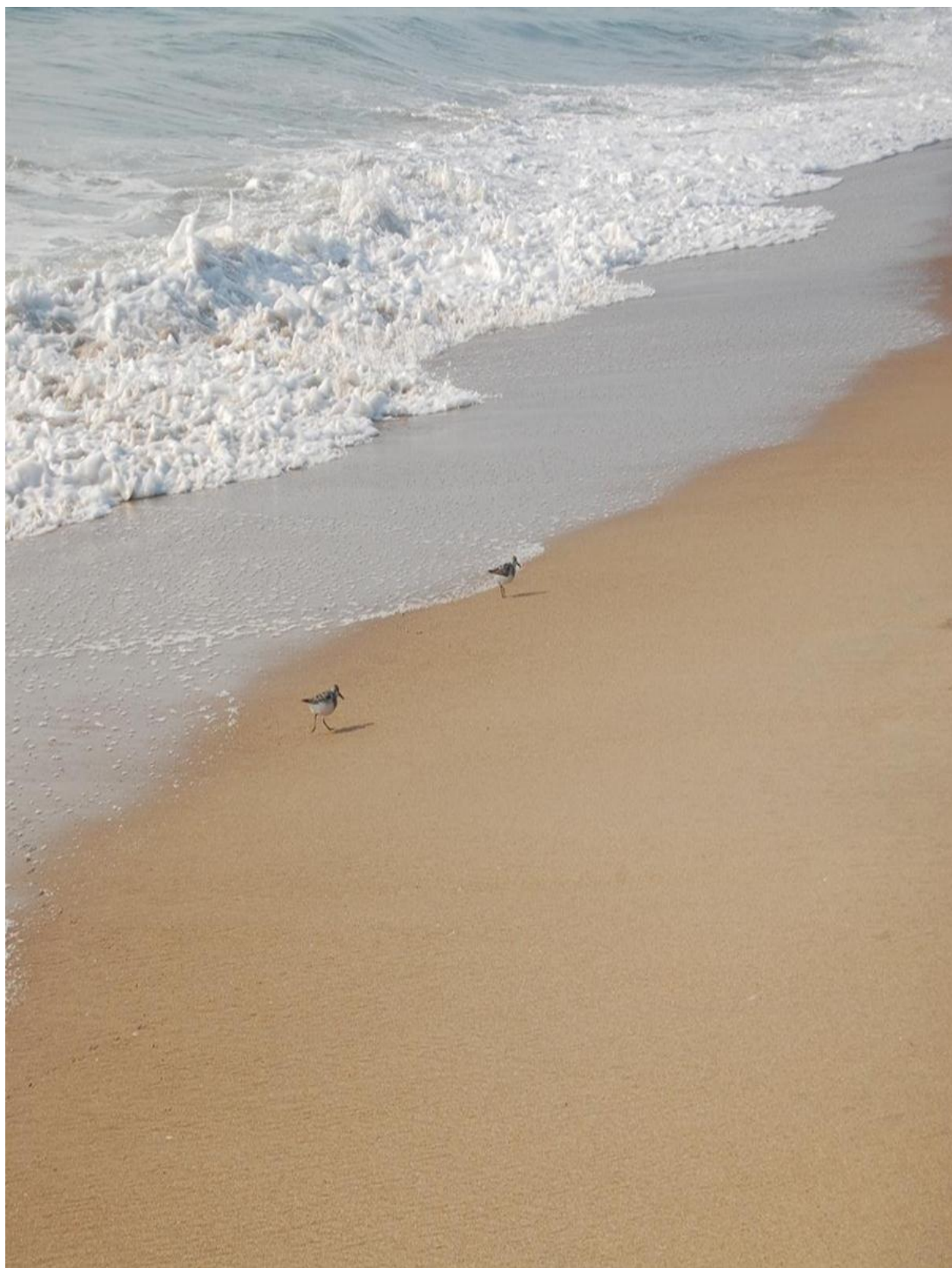
Locate a space away from the beach, clear an area, dig the trench and lay leaves first to serve as the plastic-like layer barrier to separate the sand underneath with the gravel garden.

5.

Place your t-shirt over the leaves in the trench and surrounding area. You should cut your shirt so that you can use both the front and back for a larger growing area.

6.

Next, pour the sand in the trench. You can put leaves over the visible sand so that the gravel is poured on the leaves and shirt. The leaves will naturally allow water to soak through to the gravel.





oo

1.

Identify  
available  
items  
for  
the  
border:  
large  
stones,  
wood,  
sticks,  
*etc.*

Place  
a  
border  
around  
the  
gravel  
garden.

2.

Finally, lay the gravel or rocks that you gathered from the

Finally, lay the gravel or rocks that you gathered from the ocean or river bed. Try to have a minimum of 2 inches of gravel.

3.

Because the properties of sand and rock act as filters, you can likely use the water from the ocean as long as you pour it directly on the sand.

likely

be

reduced

during

the

gravel may filter the sodium out of the water.

We have

not conducted in depth studies on the use of salt water in gravel gardens.

In river beds in the forest, you can use regular river water with no issues.

The salt in the water will

capillary

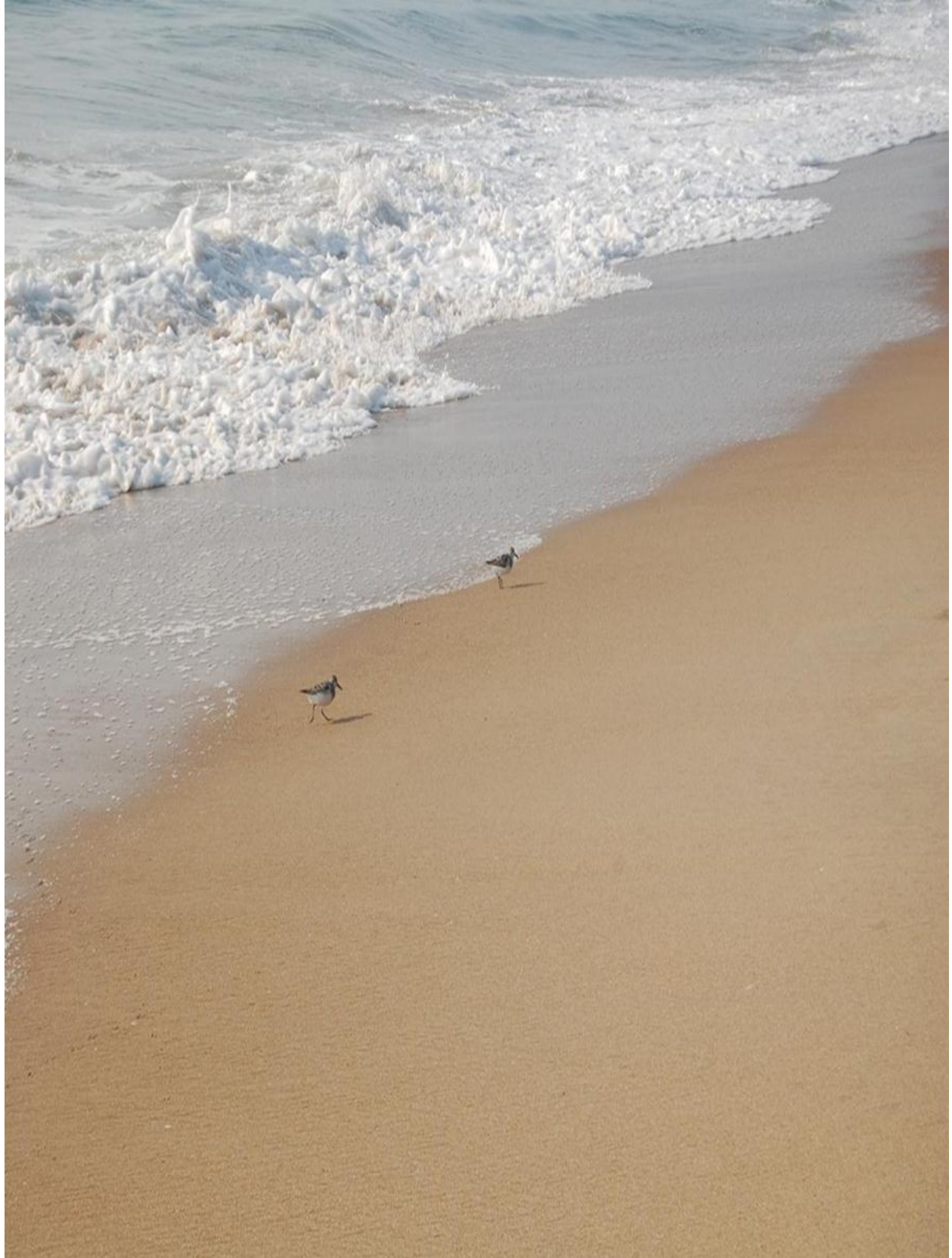
process

as

the

The only thing missing is seed, so you will need to bring your own. This application using beach materials allow coastal countries to grow crops and vegetation without the need for soil and fertilizers. Survival packs of the future will have seeds like beans and squash that seem to grow well in most river pea gravel types. The images below depicts

micro greens and peas growing in gravel from the Chesapeake Bay.





89

89

## Gravel Tools

You may use a variety of garden tools with gravel.

Shovels and these loop and stirrups hoes are recommended as they allow you to dig through the gravel to harvest the plants



plants,

roots

and

all

without disrupting the gravel.

A regular hoe can be used to smooth

gravel

when constructing your

gravel

beds.

A metal rake is also good for

pulling

up

airborne

weeds

that

may

have sprouted.

Metal rakes can also

pull up any roots if you want to begin to

plant other things in a given area.





90



## Gravel Gardening Costs

The materials needed for gravel gardening are basic sand, river pea gravel, and lawn fabric.

All of these materials can be relatively inexpensive.

A bag of river gravel costs the same as a bag of soil, roughly about \$3 to \$6 per bag.

Gravel lasts a lifetime, while soil degrades each season.

Lawn fabric can be purchased in rolls of 25, 50 and 100 feet for less than \$10 or \$50 per roll. Sand is also cheap at \$4 to \$6 per bag.

Compared to hydroponic

hydroponic

methods,

gravel

gardening is

a

fraction of

the

cost

using a

fraction of the water.

Compared

to

regular

soil

gardening,

gravel

gardening is also a fraction of the cost, as soil

needs

to be purchased annually and gravel

once purchased can last for many years to

come.

For more information, visit [www.hydroponicgardening.com](http://www.hydroponicgardening.com)



For large farms, the cost can rise somewhat,  
but when you purchase gravel by the ton, it  
cost around \$20 to \$30 per ton.

91

## Things to Remember

**Now that we have gone through the process of how to grow crops in gravel, here is a recap of things to remember and consider:**

**River Pea gravel** – The entire system is dependent on sourcing the proper type of river pea gravel. This type of gravel is generally available at most nursery retailers. The gravel in large home improvement stores may not be the best, so be sure to shop around. When laying the gravel, keep it at less than 3 inches, really 2 inches deep is ideal.

**Test First** – Before going to widespread, always test your gravel engagements in a small area using multiple types of river bottom pea gravel.

You will figure out if your construction of  
the gravel garden is successful in the three weeks after planting.

If you see the sprouts  
emerging, you are on the right track.

**Watering** – When properly constructed, your gravel garden should not require too much watering. But always examine the gravel to make sure it has not dried out. When in doubt, water again.

If you notice your crops withering, then add water and they should come back. You will need to water more with indoor gravel gardens than outdoor gravel gardens.

When you first set up your gravel garden outdoors, water until it floods. You should do this two times a week for the first two weeks.

After that water weekly.

If it rains often you

shouldn't need to water much.

**Seeds** – The normal seeds purchased at your local garden or grocery store should do well in gravel gardens.

**Level** – Make sure your planting area is level. If there is a slant, the moisture does not hold properly.

**Plastic** – Be sure to lay plastic under the fabric. When doing so poke a few holes (2 every 4

feet) in the plastic.

**Success** – Not all things will grow all the time the same way. Although we have done this for 15 years, variances can occur. You can always put in more seeds and water more. Although we have not tried it, you can always add fertilizers and compost to the gravel to assist.

We

have also found that a gravel soil mix is effective as well.

Being new to society, feel free to

experiment with gravel in your gardening process.

**Cement** – Never install a gravel garden on cement.

**Depth** – Gravel gardens must be two inches or more. Anything less can be affected by high 92

temperatures.



# Educators

## University Study

### K-12 Experiments

#### Gravel Education Introduction

To Soil Less seeks to work with K – 12, as well as, colleges and universities to study, test and experiment with the science and nutrition of gravel gardening.

Each year,

TSL issues the next edition of geological agriculture. Given that geological agriculture is a new science, there are new discoveries each year, providing new content to share.

All may contribute to the next year's gravel gardening manual, by sending photos and study results to [richard@tosoilless.com](mailto:richard@tosoilless.com)

Two bodies of work have been prepared to initiate the experimentation of gravel sciences in academia;

1)

University Academic Foundation of Discovery

1)

### K-12 Experiments

#### Academic Foundation

Geological agriculture is the process of cultivating and growing crops exclusively in gravel or rocks environment.

The relevant work summary below outlines related studies prior to geo ag that is similar to gravel gardening.

#### Relevant Work Summary

1.

**Missouri gravel bed** store bare root trees.

2.

**Agrogeology** is the method of using rock in soil as fertilizers.

3.

**Remineralization** is the process of using rock dust as fertilizers.

These three methods of gardening provide an academic foundation that rocks can play a role in agriculture.

Agrogeology uses rocks in soil and rock dust is put in soil with remineralization.

Both use rock or rock like materials in soil for the cultivation process as a natural fertilizer.

The Missouri gravel bed states that crops are not cultivated in gravel, but bare tree roots can be sustained in gravel over the winter.

This suggest that rocks have sustainment properties.

These

three

methods

substantiate

the

foundation

that



rocks

have

nutrients.

Geological agriculture takes these notions a step further by using “rocks only” to grow crops.

## **Elementary School Gravel Activity**

### **Yu Ying Elementary**

- 

#### **Session Overview**

20 minutes presentation on projector to  
give an overview of what gravel gardening  
is.

30 minutes Cup of Gravel planting and  
labeling

See following slides on the evolution of  
select seeds in cups of gravel

- 

#### **Pre Experiment set up elements:**

1 – 50 pound bag of gravel

1 – 50 pound bag sand

45 cups

45 Styrofoam bowls

Seeds

(Micro

greens,

wheatgrass,

and

beans)

2 large bins

Labels

Markers

Scissors

Experiment Steps

1.

Get 1 cup of gravel, 1 cup of sand, 1 cup of seeds, and 1 cup of water.

Simply puncture a hole in the bottom of the plastic cup.

2.

Fill  $\frac{1}{4}$  of the cup with sand and then gravel to the top.

3.

Pour small seeds on top to fall through the cracks.

4.

Place large seeds in the center of the gravel.

5.

Water to the top and let the water drip into a drip tray.

6.

Refill water when drip tray is dry.

7.

Take home after a few weeks and transplant to soil.





## Gravel Scope, Implications, and Terms

## Scope of Study



Geoagriculture studies the effects of rock, primarily sedimentary, on vegetation roots systems.

Within the process is the study of water and its effect on sand and gravel.

The nitrogen cycle process is included in the study as the source of nitrogen is critical in plant development.

Atmospheric conditions play a role

and the impact of the atmosphere can affect nitrogen fixation with the gravel.

Root systems development, micro biological analysis and plant nutrient analysis are also included in this study.

Geological considerations are paramount as there are many types of rock on the planet with many seemingly having the ability to support plant growth.

A host

of agriculture realities are included in the study with considerations on growth rates, nutrient transfer, sustainability and resilience with respect to growing crops. Analysis and studies related to the decaying process are needed to reveal the annual effect of enrichment within the gravel system.

Other analysis may

be required.

### **Implications of Study**

Defining and amplifying the ability of using rocks to grow crops absent of soil, fertilizers, and daily watering can have significant impact on the agriculture landscape.

Conservation,

sustainability

and

and

resiliency

are

achieved

simultaneously with gravel agriculture.

With the primary growing material

being rock instead of soil, the nutrients that are leach from the rock should come from that rock for decades.

Gravel agriculture can assist with climate change effects, food security issues, farming

practices,

urban

produce,

green

building

designs,

landscaping,

sustainable agriculture, environmental conservation, and job creation.

## **Terms**

**Geoagriculture** – The study of rocks to grow vegetation

**Geoag** – The abbreviated term for geoagriculture

**Gravel**

**agriculture** –

The  
application  
of  
gravel  
gardening  
techniques  
in

commercial and residential landscaping environments.

**Gravel gardening** – The process of using rocks to cultivate vegetation.

## Unanswered Academic Questions

•

Geoag is in its infancy so there are many questions not yet fully answered and explored.

The questions below represents some key questions that the study of geoag seeks to answer. All researchers seeking to expand upon the study of geoag should first read the how to manual to provide the foundation of what we know so far. The questions below are for you to explore and answer on behalf of the science:

1.

Does all river based gravel around the world provide the same benefit?

2.

What rock types have shown the best results?

3.

Can this really produce for a lifetime?

4.

Is there any structural loss with the rocks?

5.

What is it about the rocks specifically that enable nutritional transfer?

6.

How far do roots travel in gravel compared to root development in soil?

7.

How long does water store in the system before it dries out completely?

8.

What are the effects of the decaying process on the health of the gravel bed?

9.

Can the sand gravel filtering characteristics have filtering effects on sea water and gray water?

10.

How is fertilizer absorbed?

11.

Where does the nitrogen come from?

12.

Why are there inconsistencies?

13.

What is the best balance of moisture with the gravel for best growth?

14.

What crops grow best in which types of gravel?

15.

How does the growth rate in gravel compare to the growth rate in soil?

16.

What is the more precise range of reduction in water use between gravel gardening and traditional gardening?

17.

What is the nutritional impact of commonly grown vegetables and fruits?

What is the potential impact of commonly grown vegetables and fruits?  
18.

Which gravel type grows which crop type best?  
19.

What is the potential economic impact of gravel agriculture on society?  
20.

Where is the best gravel found?  
21.

What are the effects of natural fertilizers such as peanuts and compost?  
22.

What are the effects of synthetic fertilizers?  
23.

What are the greenhouse effects?  
24.

How do bugs, worms and other pests interface with vegetation in gravel environments?  
25.

How does gravel perform in commercial applications?  
26.

What is the impact of heat on rock?  
27.

Is moisture created when it is higher than 100 degrees and the depth is deeper than 2.5

inches?  
28.

What is the rate of moisture created at varying gravel depths and heat intensity?  
29.

What are the effects of varying sand levels to the development of crops or the retention of water?



RETENTION OF WATER:

30.

How do natural nitrogen fixing elements react to the biology of gravel gardening?

31.

So many more questions...

Geoagriculture or gravel gardening is a field with many questions.

The what's and how's of

gravel is still unknown.

The fundamental is known (rocks can sustain plant life), but the effects of alternative configurations and management is unknown.

To assist in the development of the

gravel gardening process, we have developed five sets of simple experiments to compare basic adjustments in the configuration to assess the effects on crop output.

Below you will find the experiment parameters, along with the initial test question, the standard and test configurations, seed recommendation and basic hypothesis. Five teams will each have two configurations to compare for a total of 10 individual gravel beds.

configuration with the test question configuration adjustment.

#

Test Question

1, 2

Does adding soil to gravel affect

growth output?

Standard Configuration

2 inches of gravel

2 inches of gravel  
1 layer of fabric  
1 inch of sand  
1 foot by 1 foot  
Weekly watering  
Test Configuration

2 inches of gravel

1 inch of sand  
½ inch of soil  
1 foot by 1 foot

Weekly watering

Seeds  
Lettuce or  
cucumbers or

beans  
Hypothesis  
Soil in small amounts in gravel can

add to the growth output of

lettuce.

3, 4

Does watering more frequently affect  
growth output?

5, 6

Does adding fertilizer to the gravel  
garden affect growth output?

2 inches of gravel

1 layer of fabric

1 inch of sand

1 foot by 1 foot

Weekly watering

2 inches of gravel

1 layer of fabric

1 inch of sand

1 foot by 1 foot

Weekly watering

2 inches of gravel

1 inch of sand

1 foot by 1 foot

Water every other day

Lettuce or  
cucumbers or

beans

Watering more frequently can add

to the growth output of lettuce

grown in gravel.

2 inches of gravel

1 inch of sand

1 foot by 1 foot

Weekly watering

Fertilize every 2 weeks

Fertilizers added to gravel can

improve growth output of lettuce.

Lettuce or  
cucumbers or

beans

7, 8

Does the presence of the cotton fabric  
have an effect?

9, 10

Is more better? Does adding soil and  
fertilizer affect growth output?

2 inches of gravel  
1 layer of fabric  
1 inch of sand  
1 foot by 1 foot  
Weekly watering  
Regular tomato seeds

2 inches of gravel  
1 inch of sand  
1 foot by 1 foot  
Weekly watering  
2 inches of gravel  
1 inch of sand  
1 foot by 1 foot  
Weekly watering  
Cherry tomato cut and left

Tomato

Decayed seeds grow better than  
normal seeds.

2 inches of gravel  
½ inch of soil  
1 inch of sand  
1 foot by 1 foot  
Weekly watering  
Fertilize every 2 weeks

Lettuce or  
cucumbers or

beans

Compare a standard

More is better. Adding more

elements to the gravel garden will

improve growth output of lettuce.

## **Monitoring**

Students teams should monitor and test the configuration three times a week (Mon, Wed, Fri) with moisture meters, ph meters, as well as, visual inspections for height, color and overall health.

If possible periodic water testing and  
nutrient testing is recommended.

Student teams should chart results and track  
for the rest of the school year or through a growth cycle.

## **Additional Considerations**

1. Students should read the manual prior to starting experiments.
2. If experimenting indoors, be sure to use containers that drain well.

Also,

assess sand dampness regularly.



Indoor, the sand tends to dry out quicker  
than when using gravel gardening techniques outdoors.

We recommend

using clear containers when indoors to better see what is happening with the  
roots and moisture in the gravel system.

(see photos of sample planting  
experiments)

3. Always be mindful of depth, too shallow and heat can burn up the vegetation.

Too deep and the shoots may not make it to the top or the water may not make it  
to the roots.

4. Never experiment on cement.

Heat will turn the cement into an oven and

cook the rock and sand from beneath.

5. Additional questions and configuration testing examples can be found in the  
To Soil Less Geo Ag Academic Foundation 2013 document found online at  
[www.tosoilless.com](http://www.tosoilless.com)

6. Feel free to run the same experiments using different seeds, gravel types,  
gravel depths, *etc.*

7. Email all results to [richard@tosoilless.com](mailto:richard@tosoilless.com).

We will feature your results in our

annual report for 2015.

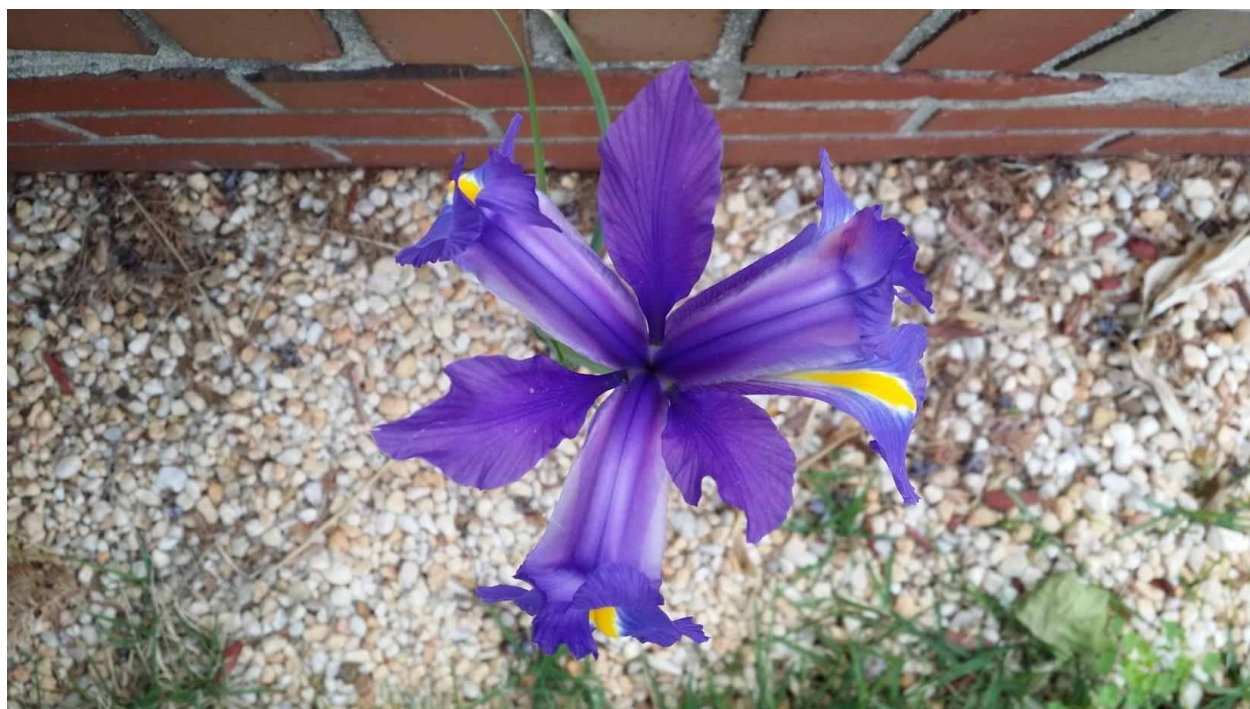
**Gravel**

**Gardening**

**Gallery**  
**2014**

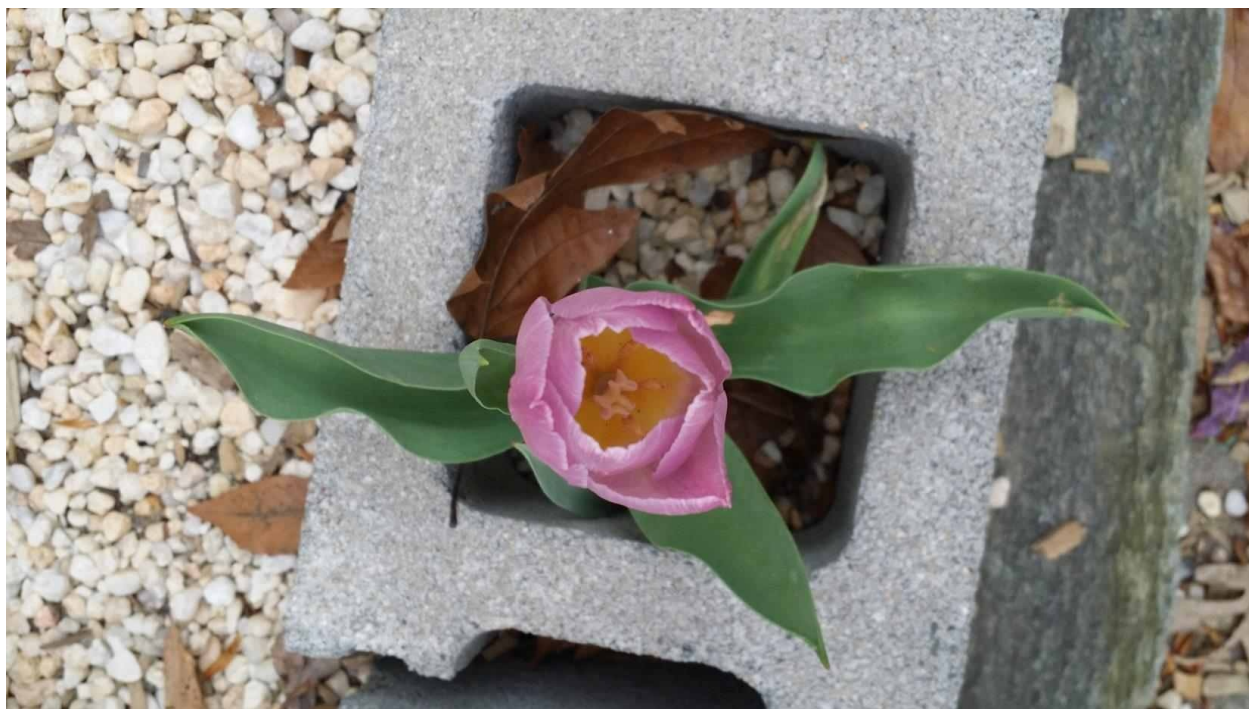




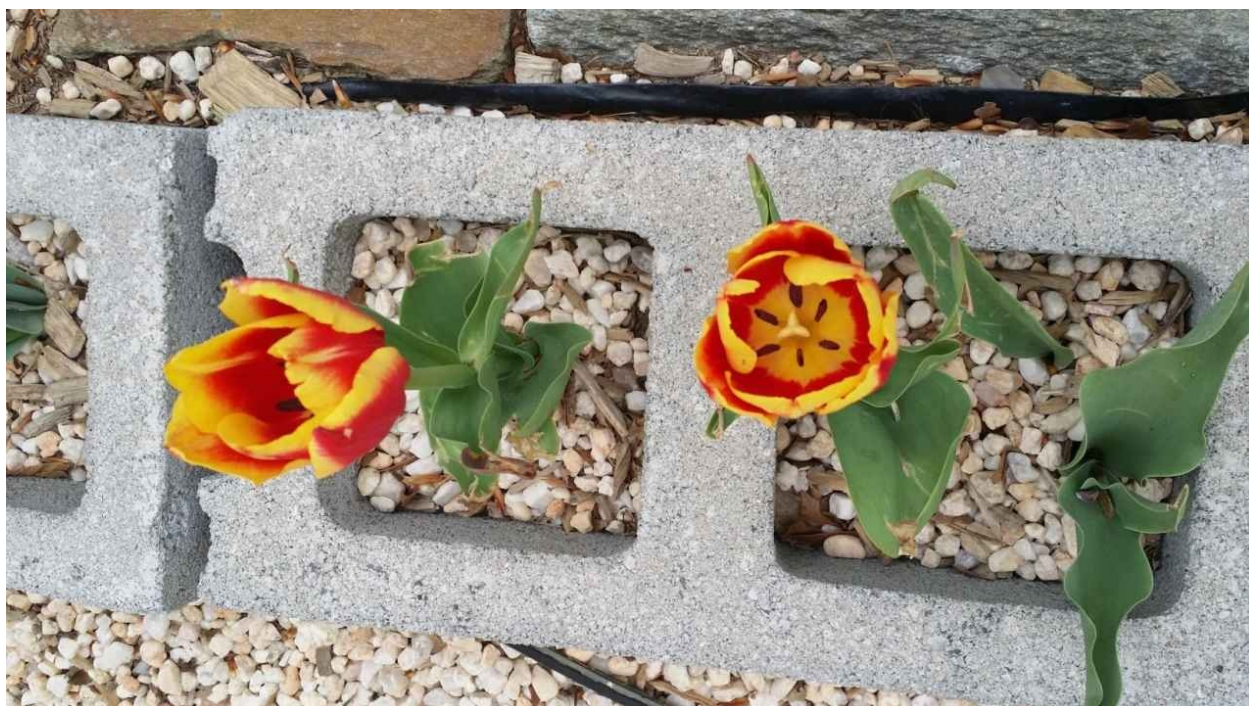


**Iris**





**Tulips**



**Tulips**





**Tulips**

**Marigolds**



Page 1

## **beans**

103





**Lettuce**



## **Onion Bloom**

104

**Squash, beans, lettuce, and corn at school gravel garden**





**Squash at school gravel garden**



105

**Mr. Veggie**





**Mr. veggie**

106

**Marigolds and Lima Beans**





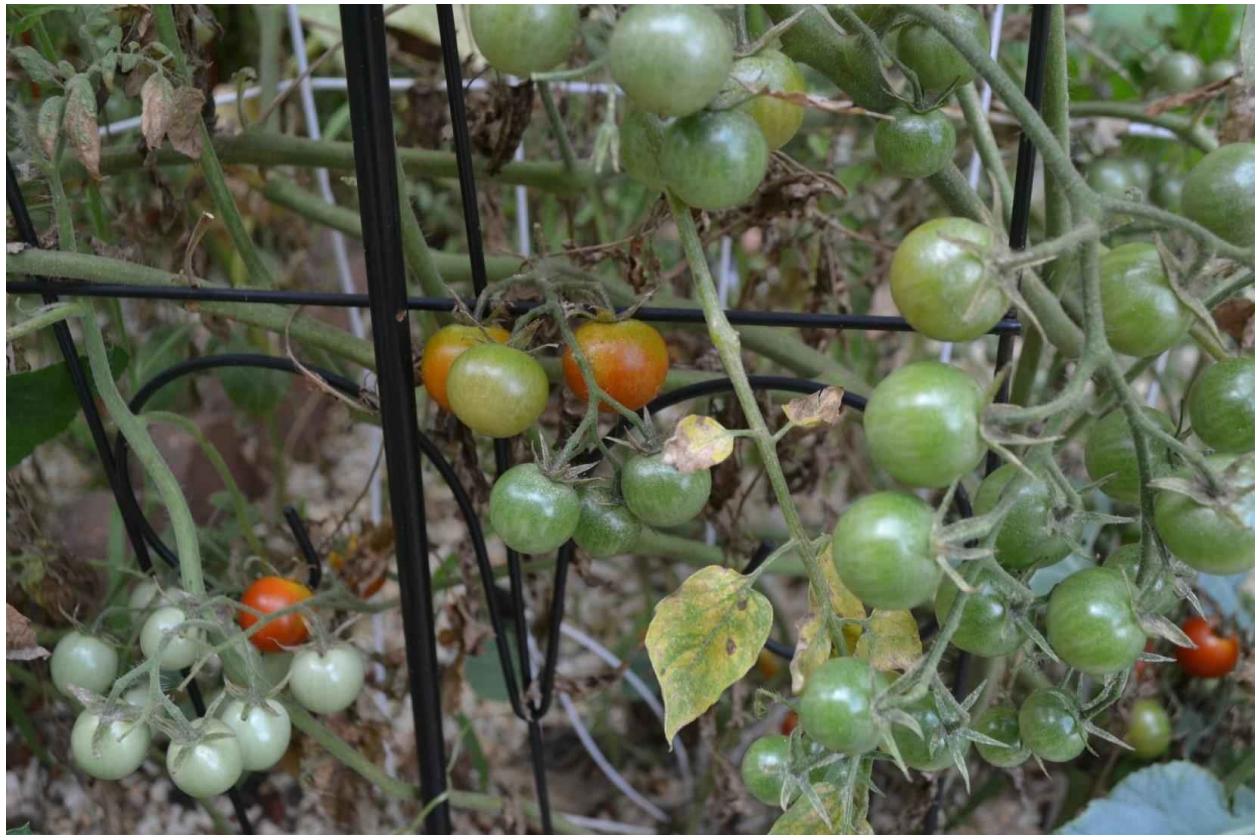
**Lima Beans**





107

**Tomatoes**





## Tomatoes

108





**Zinnia**

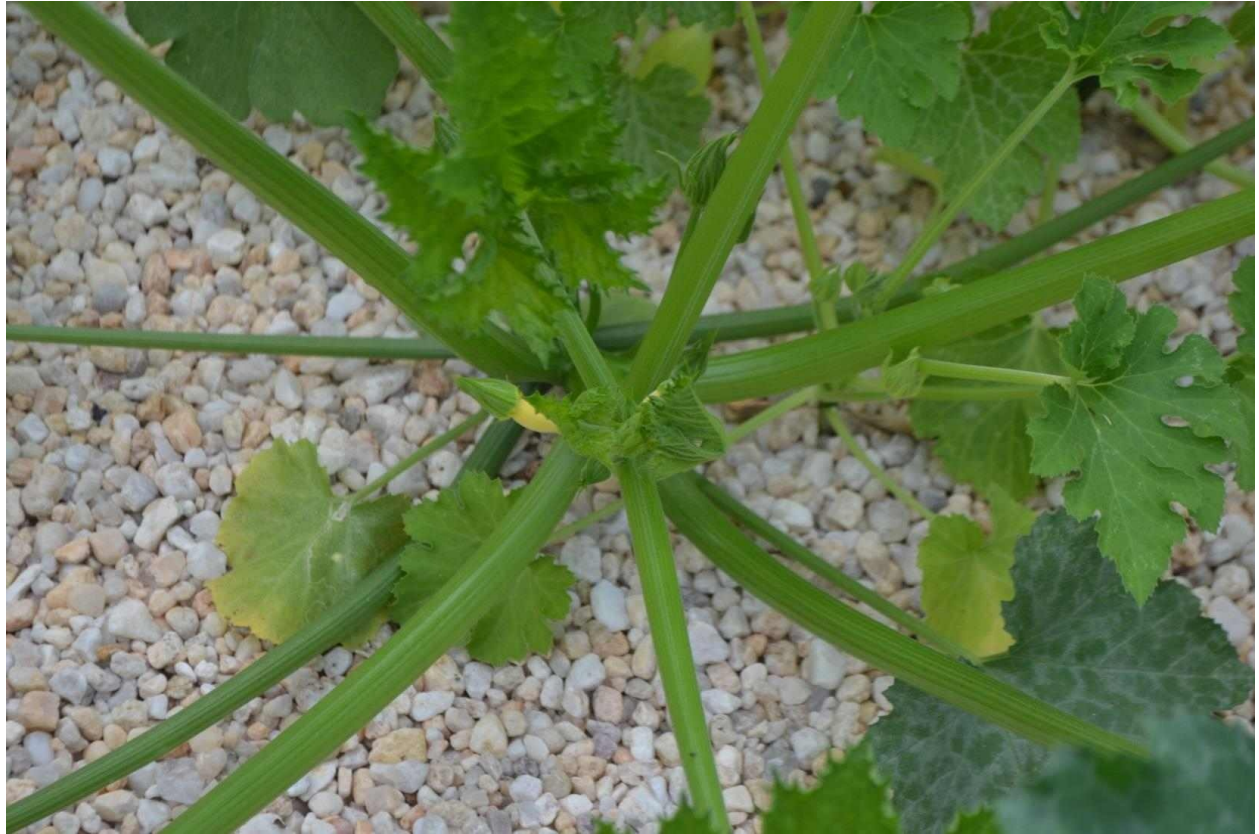


**Zinnia**

109

**Squash**







## Squash

110





**Squash, cucumbers, tomatoes, peas, lettuce at home gravel garden**



**Corn, beans, cucumber at school gravel garden<sup>111</sup>**





**Cucumber**





**Pumpkin**



**Beans**



**Lettuce**

113

**Micro greens**







**Micro greens roots**





**Wheat grass**

**Wheat grass roots**



115



**Peas and micro greens  
growing in crushed  
rock from the  
Chesapeake Bay**



**Pea roots in  
crushed rock  
from the  
Chesapeake Bay**

116

## **Glossary of Terms**

**Active layer** – The active layer of a gravel garden is the 1 to 2 inch layer of the gravel garden where root development is occurring and sustaining.

This layer touches the bottom of the gravel garden on top of the capillary fabric and goes up a few inches until the dry layer.

Within the active layer, moisture is in

contact with the gravel to activate the natural chemical action to leach materials out of the rocks for use by seeds and root systems. It is within the active layer where the ecosystem of a gravel garden sustains and feeds root systems.

**Cup O Gravel** – Small clear cups of sand and rock used to test seed development against a given gravel and seed type. Cup O Gravel is intended for testing and seedling development indoors. Cup O Gravel is not intended for outdoor use, nor is it intended for full term growth except for sprouting seeds.

**Dry layer** – The top ½ inch of a gravel garden that usually stays dry or hot under the sun.

This layer

serves as an insulation layer to the active layer, but typically stays dry itself. Referred to as the “exposed layer.” this layer looks dry in appearance compared to the active layer which appears moist.

**Enriched gravel** – Gravel that has produced crops for a full season, where the vines and leaves of the crops decay and compost back into the gravel bed, enriching the gravel with a new layer of organic material. Each year of crop production in gravel will lead to a new layer of organic material being added to the gravel bed. Enriched gravel is stated in number of years that the gravel has been producing crops.

Referred to also as appreciated gravel.

**Geological agriculture** – The study of using rocks to grow crops without soil and fertilizer. Referred to as “geoagriculture” or “geoag” or “gravel gardening.”

This science combines geology and agriculture,

where rocks replace soil in the cultivation and sustainment of plants and other vegetation.

**Gravel composting** – The process of leaves and vines decaying on and into a gravel garden where worms and other natural enzymes interact with organic substances to compost natural materials.



With gravel

gardens, composting naturally occurs as each fallen leaf quickly decays on the rocks under the sun and rain.

Gravel compost some vegetables where they will reseed themselves. A cherry tomato can be thrown on a gravel garden and it will compost and return the next or same season as a tomato plant.

**Gravel fertility** The natural capability of rocks sustain plant life.

There are over a thousand types of

sedimentary rock on Earth, each with a different level of fertility in the ability to cultivate and sustain plant development.

Sedimentary rock that produces consistent crops year after year is said to have good gravel fertility.

**Gravel juicing** – The process of adding generous amounts of seeds of a variety of crops to a gravel garden to get things going well. Until the gravel garden produces as intended, gravel juicing allow you to see what really works and does not work.

**Sand irrigation system (SIS)** – The sand irrigation system is a method of irrigation which uses sand as a water storage reservoir.

The sand is set atop of plastic in the trench to retain moisture in a gravel garden.

The SIS keeps the underbelly of the gravel garden cool and moist for long periods of time, allowing moisture to constantly impact the gravel to activate the leaching from the rocks.<sup>117</sup>

# To Soil Less

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**About To Soil Less™** To Soil Less™ – A private family company based in Washington, DC was created in 2011 for the sole purpose of sharing the gravel gardening method and technology with the agriculture and gardening industries to reduce the cost of gardening and aid in food security.

Geological agriculture is a new science defined as the study of using rocks to grow crops without soil and fertilizer. Commonly known as gravel gardening, this form of crop cultivation will bring significant sustainable agriculture benefits to populations around the world. A variety of industries will find value from gravel gardening, including home and community gardeners, real estate developers, survivalists, commercial farmers, landscapers, restaurant owners, health care providers and international development organizations. Read this and you will look at rocks differently.

**“Gravel gardening is an exciting new breakthrough for plant sciences”**

— *Arvazena (Zena) Clardy Ph.D., Assistant Professor of Horticulture, 4-H SET and NRCS Outreach, Tennessee State University*

**“I hope more people will learn the gravel planting technique.”**

— *Dr. H. Henry Teng, Dept. Chemistry Geology Program Environ. Resource Policy Program, The George Washington University*

**“It is exciting to have young children at Lowell be a part of exploring alternative gardening techniques that could have both local and global significance.”**

— *Debbie Gibbs, Head of Lowell School, Washington, DC*

**“Gravel gardening brings with it exciting possibilities for schools, inspiring hands-on, real-world lessons in science, math, sustainability, community-building, and health.”**

— *Stefania Rubino, Director of Pre-Primary School, Lowell School, Washington, DC*

**“I've always grown vegetables in the summer, but gravel gardening has increased my ability to grow well into the fall and even as late as January.”**

— *Stephen Oliver, Homeowner, Washington, DC*

**RICHARD CAMPBELL** is one of Americas top strategic thinkers and management consultants to the public and private sectors. Born in Detroit, MI and educated at Morehouse College, he served in Peace Corps and earned his MBA from Howard University. After two decades of working with top corporations, noted celebrities, and federal agencies, he founded To Soil Less to share gravel gardening practices with the world. He is married with two kids and two cats.

*Make the workmanship surpass the materials - Ovid*

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